PUMPS:

HISTORICALLY, THEORETICALLY, AND PRACTICALLY CONSIDERED.

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BY

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PREFACE.

To fully particularise even such pumps as are at present in the market, giving those desirable features which the makers from practice or vivid imagination believe to be embodied in their productions, would require a huge mass of catalogues and specifications, which, like most heterogeneous collections, would contain its quantum of unnecessary matter.

Therefore, only such examples are here taken as will make the progress of pumps sufficiently clear; novelty in design being also considered.

Of their respective merits, an appreciation or otherwise is left for the Reader; he may secure the pleasure of self-satisfaction regarding his own opinion, or, in the event of sufficient proof not being forthcoming, he may, without any great exertion, have his particular penchant firmly substantiated by any particular maker, or by any maker except that individual one, as the case may require.

To those anxious of making some new departure in pump construction, it is hoped the examples chosen will be of service. If such is the case, this Book will then have fulfilled the ulterior aim of the Author.

P. R. B.

BURTON-ON-TRENT,
1889.

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INTRODUCTION.

In reviewing the Author's 'Practical Handbook on Pump Construction,' the American paper *The Mechanical Engineer* says:—"A pump is not a very intricate machine in itself, and its parts are comparatively few; but its action, or want of it, sometimes makes it seem most mysterious."

To those who have not considered the question of water dispensation, the remark that "pumping machinery" stands pre-eminent among the various branches of engineering, may seem to allow of discussion. A few instances will very soon give the necessary proof:—

How could our coal be obtained were it not for the pumping plant?—our water supply obtained, or our capital sewage works and chemical works be carried on?

When man enters Nature's storehouse in search of wealth, he finds water ever ready to dispute his supremacy. It may be in a constant stream, varying only with the season; oftentimes vast quantities are stored in crevices

of the rocks. Some idea of the quantity of water raised will be given when it is known that often its weight is six to seven times in excess of the mineral raised. More! In Durham and Newcastle-on-Tyne it is frequently thirty times that of the coal raised.

Anybody who can use drawing instruments can of course draw a pump, but to design a perfect or practically perfect pump is more difficult. The Author has many times been told, when designing a pump, that it would be cheaper to make a certain corner square instead of round; his reply has been, "Yes, but it will not be so good for the flow of the water."—"Oh! but the advantage is infinitesimal." —"Just so, but the difference between a good and a bad pump is simply these infinitesimal parts put together, forming a very great difference."

Although the pump is so simple in itself, there are very few pumps in the market that may be said to be perfect, or anything like approaching perfection; they are spoilt either on account of cheapness in manufacture, as regards pattern making, moulding, or machining, or the maker's peculiar fancy.

The Author's idea is, in starting to design a pump, the first consideration should be perfection in the construction, totally disregarding economy and beauty; when the pump has been thus designed, look it over and try to cheapen the manufacture as much as possible without altering the construction; when that is done, make it look as nice as possible without interfering with the first two elements.

HISTORY.

The date from which we commence the History of Pumps is the year 200 B.C.; previous to that period there is no mention made of them, nor has there been discovered any portion that can be judged appertaining to such a machine.

The Heathen Chinee cannot claim any priority in this special branch, which is peculiar, the more so when we consider their manner of irrigation. A pump is even now a rarity with them.

Rude nations have not possessed the machine—simple as it is—but have always resorted to a more laborious method to obtain the water. They did sink wells, from which the precious fluid was drawn by means of pitchers attached to cords, lowered and raised simply by hand. As the possession of a well or a supply of water placed its owner in a very high standard regarding wealth, we cannot doubt that the method to obtain the same was quite a secondary consideration, and, therefore the best means known would certainly be employed. From this may be reasoned that the long continuance of draw-wells and all other methods here described, other than by means of suction, was simply because there was no superior art known wherewith the water could be obtained—that the discovery of Torricelli was original.

It does not appear to have been known to the Greeks or Romans.

In early Greek writings the words ἀντλος, ἀντλειν, ἀντλια, &c., were not used to express anything like what we call a pump. It either expresses the draining of water,

or more particularly the raising of it by means of a bucket or some similar vessel. 'Αντλος, the primitive, is a drain, sink, or receptacle for collecting scattered water, either for use or otherwise.

The Egyptian wheel was a common machine over all Asia, and in remote corners remains in use yet. The Saracens carried it to Spain, where at the present time it works under the name of "Noria."

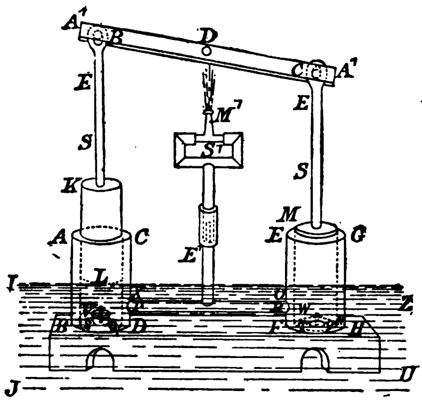
Danish missionaries in a remote village in the kingdom of Siam discovered the immediate offspring of the "Noria," consisting of a wheel turned by an ass, and carrying round it, not earthenware pots, but a band of hay, which being drawn through the water, collected the fluid upon it, and delivered it up through a wooden trunk.

The performances of Ctesibius and Hero are by Pliny and Vitrùvius spoken of as curious novelties. Hero, an engineer and inventor of the Alexandrian school, that capital where most of the sciences were born, mentions the pump by Ctesibius in his work on 'Pneumatics,' wherein are contained treatises upon the expansion of steam, the slide valve, the spindle valve, the common clack valve, illustrating the application of a metallic piston to a metallic cylinder, and nearly one hundred other inventions are described and illustrated, which at the present time would be classified under the head of Mechanical Engineering. The clear manner in which they are described leaves no doubt of the advanced knowledge possessed by the ancients of that class of mechanism of which the steam engine has been structurally compounded. The pump stands nearly last on the list.

The pump mentioned by Hero is illustrated in Fig. 1. This illustration and the following description are taken from Mr. Bennett Woodcroft's English translation of Hero's 'Pneumatics':—

"The siphons used in conflagrations are made as follows. Take two vessels of bronze A B C D, E F G H, having the inner surface bored in a lathe to fit a piston (like the barrels of water-organs), K L, M N being the pistons fitted to the boxes. Let the cylinders communicate with each other by means of the tube X O D F, and be provided with valves P, R, such as have been explained above, within the tube X O D F, and opening outwards from the

FIG. 1.



cylinder. In the bases of the cylinders pierce circular aperture S, T, covered with polished hemispherical cups V Q, W Y, through which insert spindles soldered to, or in some way connected with, the bases of the cylinders, and provided with shoulders at the extremities that the cups may not be forced off the spindles. To the centre of the piston fasten the vertical rods S E, S E, and attach to these the beam A′ A′, working at its centre about the stationary pin D, and about the pins B, C, at the rods S E, S E. Let the vertical tube S′ E′ communicate with

the tube X O D F, branching into two arms at S′, and provided with small pipes through which to force up water, such as were explained above in the description of the machine for producing a water-jet by means of the compressed air. Now, if the cylinders, provided with these additions, be plunged into a vessel containing water, I J U Z, and the beam A′ A′ be made to work at its extremities A′, A′, which move alternately about the pin D, the pistons, as they descend, will drive out the water through the tube E′ S′ and the revolving mouth M′. For when the piston M N ascends, it opens the aperture T, as the cup W Y rises, and shuts the valve R; but when it descends, it shuts T and opens R, through which the water is driven and forced upwards. The action of the other piston K L, is the same. Now the small pipe M′, which waves backward and forward, ejects the water to the required height, but not in the required direction, unless the whole machine be turned round; which on urgent occasions is a tedious and difficult process. In order, therefore, that the water may be ejected to the spot required, let the tube E′ S′ consist of two tubes, fitting closely together lengthwise, of which one must be attached to the tube X O D F, and the other to the part from which the arms branch off at S′; and thus, if the upper tube be turned round, by the inclination of the mouthpiece M′ the stream of water can be forced to any spot we please. The upper joint of the double tube must be secured to the lower, to prevent its being forced from the machine by the violence of the water. This may be effected by holdfasts in the shape of the letter L, soldered to the upper tube, and sliding on a ring which encircles the lower."

In the year 1550, Agricola writes that pumps were then used in the German mines, driven by horse-power and water-wheels.

Although the pump was invented 120 B.C., it was not until the beginning of the 17th century that its true principles were understood, it being generally thought to act by means of a force called suction, though no attempt to discover the reason why water rose upwards under a piston was made until the time of the Duke of Florence, when the pump-maker to his Royal Highness, in the year 1641, complained that the water would not rise higher than 32 feet or thereabouts. Galileo was applied to for a solution, but does not seem to have solved the question. His pupil Torricelli considered that the atmospheric pressure might be the counterpoise to the 32 feet of water when received into vacuum; the experiment was tried in 1643, and the supposition was found correct. From this experiment emanated the discovery of the barometer.

The earliest representation of a bellows pump met with, is among those curious cuts embodied in the first German translation of Vegetius, published in Erfurt in 1511. It consists of an ordinary pair of bellows, the lower side or board of which was fitted with a valve and suction pipe, and the blast pipe or nozzle was fitted with a delivery pipe.

Dutchmen have played no small part in the history of hydraulic engineering, and to one London was indebted for its first water supply. From Allen's 'History of London,' vol. iii. page 467, we gather—"One Peter Morris, a Dutchman, in the year 1582, contrived a water engine or mill to supply the citizens with Thames water. This machine was first made to force the water to the height of Gracechurch Street only. He obtained from the City a lease for 500 years, at the yearly rent of 10*s.*, for the use of the Thames water, and a place for sinking his mill upon."

Stow, in his 'English Chronicles,' speaking of these

waterworks, says:—"Peter Morris, free denizen, conveyed Thames water in pipes of lead over the steeple of St. Magnus' Church, at the north end of London Bridge, and so into divers men's houses in Thames street, up to the north-west corner of Leaden Hall (the highest ground of London), where the waste of the main pipe ranne first in the yeare (1582) on Christmas even; and since being divided into foure spoutes, oft times running foure wayes, plentifully serving to the commodity of the inhabitants neare adjoining to their houses, and also cleaning the canals of the streets towards Bishoppesgate, Aldgate, the Bridge, and the Stockes market."

While excavating for the north foundation of the present London Bridge, several curious things were brought to light. Among others were two cylinders or pump barrels, formerly belonging to some waterworks erected upon the spot; they were of cast-iron, 4 feet long, with a bore of 5¾ inches diameter, and each was furnished with trunnions, similar to a cannon, for the purpose of securing them in their places.

These forcing pumps appear to have been immersed in the water whence the supply was taken, the suction or feed pipes being only 4 inches in length. The feed pipe of one, and the delivery pipe of the other were of brass, very neatly united to the iron by brazing. The valves were not seated within the cylinders, *but in separate chambers.*

That these waterworks were buried in the ruins of the great fire of 1666 there seems very little doubt from the appearance of one of the oak piston-rods, of such size as to nearly fill the cylinder, being burned down some little distance within the cylinder in a conical shape, and in a better state of preservation than the other part. This piston was at the bottom of the stroke, the other being at

the top of the stroke, the piston-rod whereof was missing, having been, no doubt, burned away, both pistons remaining in their respective positions. From one of the cylinders was drawn out a half-burnt cock.

Together with the cylinders was found a largo square shaft, which appears to have carried a cross arm (which was probably of timber, and consumed in the fire), from each end of which a piston-rod was attached. The axis of this shaft was very much worn on the underside, as though it had performed a reciprocating motion in an arc about 90 degrees.

This is the first instance the author has found in which the valves were placed *in separate chambers*, all previous pumps having the suction valve and pipe in a direct line with the piston or plunger, and the delivery valve chamber fixed at the top of the working barrel.

Mr. Frank H. Pond, of St. Louis, states that:—"The introduction of pumping machinery for domestic water supply dates from May 30th, 1581, when Peter Maurice was granted a lease to erect an engine within the first arch of London Bridge for the purpose of supplying that city with water. These works proved so successful that he was granted the privilege of erecting another engine in the second arch of the bridge."

"This pumping machinery consisted of an undershot wheel 20 feet diameter, having 26 floats, 14 feet long by 18 inches broad. Each wheel gave motion, by means of toothed wheels and levers, to sixteen pumps, in such a manner that for every revolution the plungers made two and one-fifth strokes 2 feet 6 inches long. The plungers were 7 inches diameter, and when the tide flowed quickly the water wheels would together be thus pumping at the rate of 2½ million gallons in twenty-four hours."

The first patent record in England of a pump is Patent

No. 6, year 1618, entitled "Engines and Instruments for Raising Water," by David Ramsey and Thomas Wildgosse. As the beautiful law demanding two copies of drawing illustrating the inventions, when necessary, was not then in vogue, we must surmise that either his method was very simple or the reverse, neither illustrations nor description being given in the Specification.

The air-pump, for extracting the air from a vessel, whereby it is said that the air is exhausted, or a vacuum produced, was invented by Otto de Guericke in the year 1654.

About the year 1660 Robert Boyle made so many improvements in the air-pump, that it became almost a new machine.

Sir Samuel Morland, Master of Mechanics to King Charles the Second, in the year 1674 invented and patented the plunger pump made of cast-iron.

The following is a copy of the Specification, which is dated March 14th, 1674, Patent No. 175 :—

"Charles the Second, &c., to all to whome these presents shall come greeting.

"Whereas our trusty and well-beloved Sir Samuel Morland Knt. and Bart. hath with long study and greate expence invented and brought to perfection 'Several 'Engines for Raising great Quantities of Water with farre 'lesse proportion of Strength than can be performed either 'by any Chayne Pumpe or other Engine or Pumpe now in 'use,' several demonstrasions whereof wee have seen to our greate satisfaction, and believe the same will prove of greate and universal use to our subiects. And the said Sir Samuel Morland hath assured us that hee will make very considerable and useful improvements and additions thereunto; and also humbly besought us to grant him our licence for the sole use and benefit of the said

engines for the terme of fourteen yeares according to the statute in such cases made and provided." The remainder of the Specification contains nothing but warnings, that nobody else is allowed to make anything like his machine, and to prove that any such punishment would not be a pleasure to the Patentee, means were taken to prevent other persons making such machines; for neither description nor illustrations are given. Evidently an engineer's statement was accounted something in those days.

In the year 1681, we have for the first time information given of an engineer being presented with a medal for excellency of work in pumping machinery, the honoured gentleman being Sir Samuel Morland; and well he deserved such a mark of esteem. He raised water from the Thames sixty feet above the top of Windsor Castle, at the rate of sixty barrels per hour, by eight men, in the year 1675, which gave so much satisfaction, that in the year 1681 the King presented him with his medallion portrait set in diamonds.

One of the most important features in plunger pumps and "dry spear" pumps, as also in the steam engine, is the gland and stuffing-box, which is therefore worth a little discussion, especially as James Watt has been credited with its invention.

Mr. William Pole, in his 'Treatise on the Cornish Pumping Engine,' published in the year 1844, says:—"The plunger pump was invented by Sir Samuel Morland, and patented by him in 1675. The best feature in Sir Samuel's invention is the *stuffing-box*. This last-named contrivance, whose universal utility is testified by its very general use, and without which the steam engine could scarcely exist, is undoubtedly the invention of this distinguished and ingenious man, and alone ought to render his name immortal."

Again, Mr. G. G. Andrée, in his valuable book 'Coal and Metal Mining,' p. 430, states: "This kind of pump possesses many advantages over the preceding. The plunger variety, which is by far the best, was invented by Sir Samuel Morland, in 1675. A remarkable feature in this invention is the stuffing-box, without which the steam engine could hardly have come into existence."

Mr. Edward Alfred Cowper, in his paper "James Watt," read before the Institute of Mechanical Engineers, says:—"Watt invented the *stuffing-box* in the year 1782, but Watt's notes on Mr. Robinson's article on 'Steam and Steam Engine,' written for the 'Encyclopædia Britannica,' show that he was using it about 1774."

In a letter by Mr. Joseph Bramah, of hydraulic press fame, 1797, to Sir J. Eyre, Chief Justice of the Common Pleas, he strongly urged the demolition of Watt's patent. Bramah's chief objections were, that Watt's engine was much more complete than the Specification in details, more particularly in:—

1st. The cylinder top being closed;

2nd. Ingenious piston, and valve-rod *stuffing-box* in the cover;

5th. Construction of *stuffing-box*.

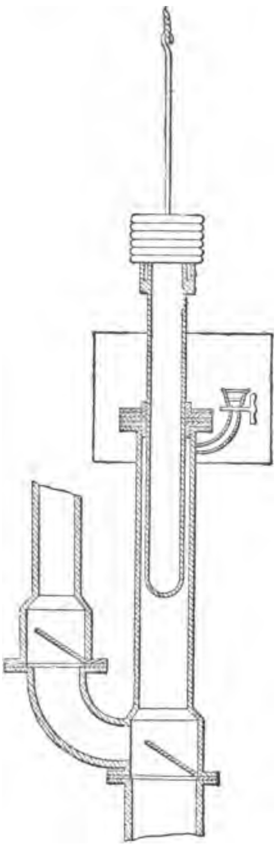
From these contradictory evidences the author concluded that what Mr. Pole and Mr. Andrée referred to was the substitute for a gland and stuffing-box described in the following manner in the 'English Encyclopædia,' published in the year 1802:—"The forcing pump is sometimes of a very different form from that already described. Instead of a piston, which applies itself to the inside of the barrel, and slides up and down in it, there is a long cylinder nicely turned and polished on the outside, and of a diameter less than the inside of the barrel. This cylinder (called a plunger) slides through a collar of leathers on the

top of the working barrel, and is constructed as follows:—The top of the barrel terminates in a flanch, pierced with four holes for receiving screwbolts. There are two rings of metal, of the same diameter, and having holes corresponding to those in the flanch, four rings of soft leather, of the same size and similarly pierced with holes, are well soaked in a mixture of oil, tallow, and a little rosin. Two of these leather rings are laid on the pump flanch, and one of the metal rings above them. The plunger is then thrust down through them, by which it turns their inner edges downwards. The other two rings are then slipped on at the top of the plunger, and the second metal ring is put over them, and then the whole are slid down to the metal ring. By this the inner edges of the last leather rings are turned upwards. The three metal rings are now forced together by the screwed bolts; and thus the leathern rings are strongly compressed between them, and made to grasp the plunger so closely that no pressure can force the water through between. The upper ring just allows the plunger to pass through it, but without any play; so that the turned-up edges of the leathern rings do not come up between the plunger and the upper metal ring, but are lodged in a little conical taper, which is given to the inner edge of the upper plate, its hole being wider below than above. It is on this trifling circumstance that the great tightness of the collar depends. To prevent the leathers from shrinking by drought, there is usually a little cistern formed round the head of the pumps and kept full of water. The plunger is either forced by a rod from a working beam, or by a set of metal weights laid on it." This pump is illustrated in Fig. 2.

The author is fully convinced that Sir Samuel Morland was the original inventor, and that James Watt only applied it to the steam engine. Although Mr. E. A. Cowper,

in his paper read before the Institute of Mechanical Engineers, stated that Watt was the inventor, he afterwards, in a paper on 'The Steam Engine,' read before the Institute of Civil Engineers, January 17th, 1884, states that:—"Sir Samuel Morland, in 1682, proposed to the French Government to raise water by the force of steam, but failed to get his plan taken up. There is no description of it extant. In 1674 he had invented a *stuffing-box* to his *gland*."

FIG. 2.



In the year 1695 is the first notice the author has found relating to "ship pumps." In that year one was patented by Robert Ledgingham; it is to be regretted that the Specification in this, as in all other of that period, is void of drawings and description of the invention.

In the 'Complete Collier,' published in England in 1708, it is stated:—"In some places we draw water with waterwheels or long axle-trees, but there is not that convenience of water everywhere." The axle-tree referred to worked upon a long axle, having attached to it a series

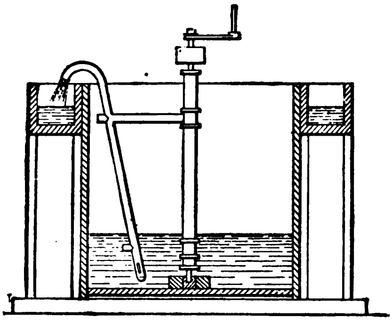
of oblong wooden buckets or troughs, which filled at the bottom of the pit and discharged at the top, as they turned over the great axle-tree. The author of this work is reluctantly obliged to admit that he and his brethren knew of no means whereby the drainage of the "good collieries," which lie unwrought and drowned, "could be accomplished," adding that those who could devise such methods "might keep their coach and six, for we cannot do it by our engines."

Apparently no one in the north of England or Scotland was capable at this time of constructing even a common pump. This circumstance may be gathered distinctly from the records of the family of Mar. In 1709, the Earl of Mar sent his colliery agent to Newcastle-on-Tyne, it being then, as now, regarded as the head school of mining, and from the manager's report it appears the machines in use were water-wheels and horse engines, with chain pumps for raising water. The Earl called in the aid of George Sorocould, an engineer from Derby, to assist and advise his plans. Sorocould knew what a pump was, for he recommended their adoption. But when he went away no man could be found to put his plan into execution. John Young, the millwright of Montrose, was referred to; then a gentleman in Holy Orders was consulted, the Mechanical Priest of Lancashire—not the only instance of spiritual advisers being able to advise upon matters temporal and mechanical—the result being that the chain and bucket gave place to pumps worked by cranks and beams receiving their motion from water-wheels.

The earliest record of any pumping engine is found in Stewart's 'History of the Steam Engine,' published in 1714, where one John Potter, of Chester-le-Street, in Durham, constructed a pump 9 inches in diameter, made of elm hooped with iron.

In the year 1732, M. Demour, a Frenchman, proposed to raise water by putting into rapid rotation pipes spreading at the top like a V. This was the first attempt at making a centrifugal pump; it is illustrated in Fig. 3. The next

FIG. 3.



step was the inverted Barker's Mill or a revolving T, and the best form of this species of pump was investigated by M. Euler.

James Creed, in the year 1741, secured a Patent, No. 579, for "Three different Engines or contrivances for cutting sheet Lead into any required breadths, for Making of Water-pipes of any Diameter and Strength, according to the Service required, and for the Covering of Churches, Houses, and all other Buildings with such Lead, or with Coppar or Brass, after a manner not hitherto used; and also a New Pump, Engine, or Forcer, for Raising of Water with a Perpendicular Stroke, which will answer the Purpose of a Common Pump, or of an Engine to Raise Water to any Usual Heighth, or the Extinguishing of Fire."

As the lead pipes have nothing to do with our subject, we will only give that part of the specification relating to the pumps.

"The Body of this Pump, Engine, or Forcer, is made up or put together into one piece, consisting of an Air-vessel, with one, two, three or more barrels, each Barrel having a Sucker or Bucket, with a rod through a small hole in a cap, which screws on or is fastened by nuts and screws to and cover the head of the Barrell with leather for the rod to work through, fastened by screws or otherwise to the cap, that little or no water may come through the same; and as the water rises in the Barrell, it is delivered into a pipe lett into the Barrell near the top, and soldered thereto, which pipe extends down the side of the Air-vessell to the bottom thereof, where the said pipe is open, and communicates with the air contained in the said vessell; and the said pipe also extends upwards into an open cistern at the head of the said Barrell, with a stop-cock or screw at the head of the said pipe, which being open, the water as it rises in the said barrel is delivered through the said stopcock or screw unto such open cistern, and thence through a nossill, as in common pumps; but by turning the said stopcock, or fixing a cap on the said screw, the water is forced, by means of compressing the air contained in the said air-vessell, into another or additional pipe lett in and joined to the said first-mentioned pipe, near the top thereof, and is conveyed through such additional pipe in a continual steam to any usual height or with a great velocity through a brass or copper elbow and pipe for extinguishing of fire, and with or without leather pipe, as used in such cases; or any of the said last-mentioned pipes may be screwed or fastened on to the stopcock or screw in the pump cistern, or to any stopcock, screw, or pipe placed in any other part of the said first-mentioned pipe communicating with the air-vessell. The above is the method of working this engine as a lifter, and it may be worked as forcer by omitting the cap to the barrell and changing

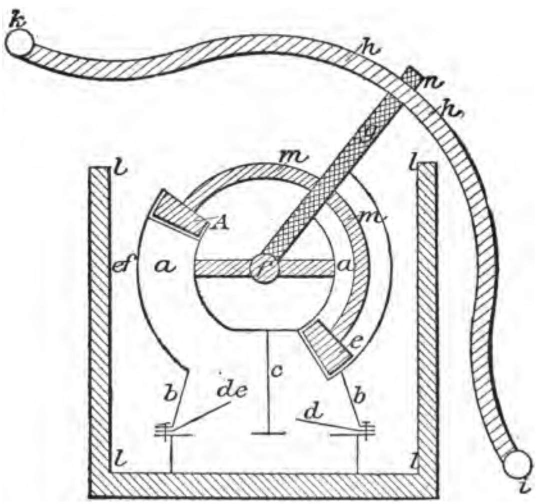
the buckett for a plunger or forcer, and changing the place of delivering the water out of the barrell into the pipe, by letting such pipe into the barrell near the bottom thereof instead of near the top, and with the addition of a valve in such pipe, fixing the pin which passes through the lever, and on which the same works, on the farther side of the perpendicular rod from the handle, which, in the case of a lifter, is fixed on the side nearest the handle. The barrell, pipes, air-vessel, and pump cistern are made with copper, brass, or lead, or part of one and part of the other, fixed in a frame or case of timber, strengthened with iron work; and this pump, engine, or forcer is to be worked by lever, pendulum or swing handle, wheel or crank, and by the power of men, horses, wind, water, fire, or any other power. The mechanical contrivances for working with a perpendicular stroke is by means of a slit or eye in the lever or handle working on a roler, or a plain handle or lever working between two rolers, the roler or rolers for this purpose being placed in a slit or eye in the rod of the pump, engine, or forcer; and for guiding the rod perpendicular, there are two wheels working against upright pieces, and turning on their axes, which pass through the rodd, the said wheels placed either on each side of the said roler or rolers, on which the handle works, or one above the other below the same, or those wheels may be omitted, and it will work perpendicularly, being guided by cross pieces for the rodd to work through as regulators, with or without wheels in such cross-pieces; and by means of shifting the pin or centre of motion on which the lever or handle works, the stroke may thereby be lengthened or shortened, and consequently more or less water delivered at each stroke, in proportion to the height it is to be delivered at, or to the velocity at which it is to be thrown, and the power to be applyed."

The first oscillating pump is in all probability the one patented in the year 1750, Patent number 658, by William Perkins. The illustrations and the following description are taken from the Patent Specification. "Machines for Grinding Corn, raising and forcing water, &c.

"What I first describe is particularly useful to raise water and other fluids.

"Two curved barrells of Brass or other metal marked *a*, *a*, Fig. 4, fixed to the Engine Tree of the same metal *b*, *b*,

FIG. 4.



with a partition *c*, to prevent the communication between the two barrels, in the said Engine Trees are two valves *d e*, *d*, in the two Barrels are two Pistons or Forcers, leathered so as to fit the barrels, *e f* and *e*; *f* is the place for the centre of the axes from which the iron rod *g* communicates with the two Forcers *e f* and *e*, and the two handles

h, *h*, in the two holes at the ends of the iron handles *i k* is to be fixed two wood handles for the men to work by, *l l l l* is a wood cistern (to receive the water) in which the Engine Trees &c. are fixed, when ye handle *i* is raised it raises the forcer *e* and lower the other *ef*, and at the same time the valve *d* opens and the other *d e* shuts which by raising one forcer and lowering the other alternately will raise the water into the Engine Trees and Barrels and from

FIG. 5.

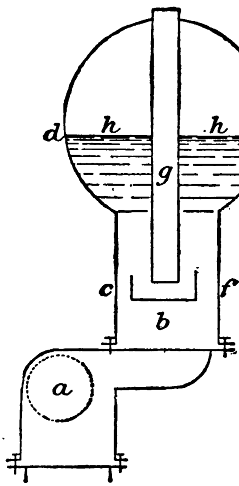
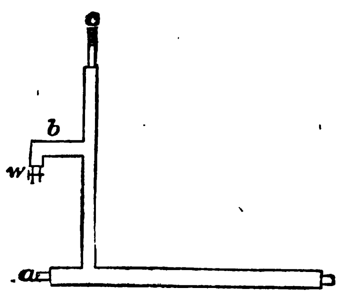


FIG. 6.



thence force it through two valves at the top of ye Engine Tree marked *b* Fig. 5, and from thence to ye place intended, when you would work it by wind, water, or horses, the power may be communicated to it by the common way. Fig. 5, is a side view of ye Engine Tree with the air-vessell when used for extinguishing Fire. *a* is that part of the Engine Tree where ye Barrels are fixed, *b* the

place for the two valves, one on each side of the partition marked *c*, in Fig. 4. *c*, *d*, *e*, *f* the air-vessell, *g* the pipe leading to the Branch pipe with ye lower end turned upwards on two sides to prevent ye air from going through ye s[d] pipe with the water if any air should by accident be drawn into the Engine Tree for by this means if any air goes through the valves at *b* it cannot go directly into the Pipe but will go through ye water and enlarge ye quantity of air *h h*. Fig. 6 is a side view of ye axis and crank &c. which I could not show in Fig. 4. The Gudgeon *a* is to go through ye centre *f* in Fig. 4. The crank *b* with cheeks is to receive ye two forcing rods *m*, *m*, in Fig. 4 w[th] a pin through them. The iron rod *c* is to go through ye curved handle of *n* Fig. 4."

The oldest waterworks in the United States of America are supposed to be those of Bethlehem, Pa, which were built in 1754, by Christopher Christiansen, a millwright, a native of Denmark. The water was conducted 350 feet, through an underground conduit into a cistern, whence it was pumped by a lignum vitæ pump of 5 inches bore, through bored hemlock logs, to a height of 70 feet, into a wooden tank in the village square.

John Ward, in his 'History of the Borough of Stoke-upon-Trent,' referring to James Brindley's pump, says: "But after pumping out the mines for fully forty years after his death, it was broken up, about the year 1812. The pump trees, which consisted of wooden staves firmly bound together with ashen hoops, were found to be lined with cow-hides, the working bucket being also covered with leather, a contrivance the like of which it is believed has not before been recorded. The pump was made about 1757."

In the year 1760, Thomas Perkins secured a Patent for "Engines for raising and forcing water." His claims are :—

"*1st*, the cistern is about 7 feet long by 20 inches wide, by 19 inches."

"*2nd*, it is to have four wheels, to be driven by men or horses."

"*3rd*, the water ways are about 4 inches diameter, with a suction cock 4 inches bore. It has 4 cylinders or barrels, about 6 inches diameter, which are to be fixed on the water ways in a square, which work is fixed in the middle of the cistern. In each cylinder or barrel is a piston, which drives and forces, when drawn up it fills the barrels, and when forced down the water is forced into the air-vessel, which is fixed between the four barrels, which, by the help of the pressure of the air, throws it through the stand pipe to the place intended. The air-vessel is covered by a case, and at the upper end of one of the stand pipes is a cock to turn on occasion to make the water ascend out of one of the pipes to a much greater distance."

Christopher Christiansen, in the year 1762, constructed larger waterworks for Bethlehem, Pa. An 18 feet undershot water-wheel drove three single-acting pumps of iron 4 inches bore and 18 inches stroke.

At the Dolcoath mines in the year 1765, there were working two atmospheric steam pumping engines, the water from which, on its way to the lower level of the new adit, by its passage over two water-wheels with cranks on their axles attached to beam-worked pumps. The minerals from the mine were raised by horse-whims, and water was elevated by the same means in buckets and kibbals from the shallow levels, showing that the steam pumping apparatus had not driven the horse quite out of the field in 1765, nor had the pump-barrel entirely superseded the original tub.

For many centuries the pump used in the tin mines in Cornwall were of a rude description, consisting of a pipe

having a square leather bag attached to a long wooden handle, doing duty as a bucket. As increased depth overtaxed the strength of this structure, cylindrical wooden pumps were made bound by iron hoops. The rag and chain pump then came into use. This was composed of an endless chain, moving upwards through the pump, having attached to it at every two or three feet a piston made by a ball of rags bound together, or of wood edged with cloth or leather, for up to this time valves had not been used in Cornwall.

In Mr. Richard Trevithick, senior's, account book, closing in 1775, we find that the "Dolcoath pumps were made at Coalbrookdale" (the once famous Shropshire ironworks, founded by Mr. Abraham Darby about the year 1658), "for the art of casting pumps was not at that time known in Cornwall."

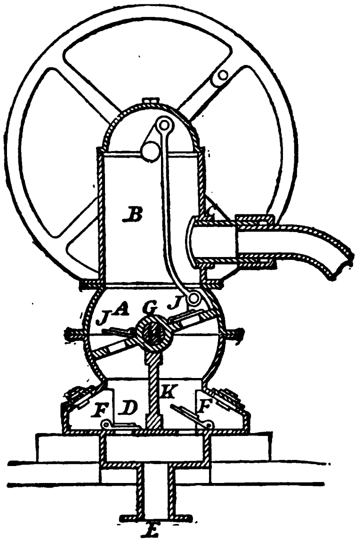
It appears rather singular that the admirable invention of *separate valve chambers*, referred to in connection with the first London waterworks, should have been lost to sight for so many years—viz. from 1580 to 1792 (a space of upwards of two centuries), then to have been brought forward as a new invention. This was done by Mr. Charles Simpkin, who procured a Patent for the same in January 1702. In this Specification Mr. Simpkin states that, "my invention consists in exploding or removing the valves both from or out of the part or parts of the cylinder or cylinders where the vacuum is made by the piston, fan, or fly, or by what other name soever it may be called or denominated, and from under or out of the air-vessel, and in placing, inserting, or making use of the valves in the following manner, by application of certain receptacles or chambers, for the express intent and purpose of containing the valves only, thereby rendering the valves more free of access and preventing the necessity of

opening any other part of the engine, except those chambers where the valves are contained. Of this improvement I say that all chambers or receptacles for containing the valves are hereby considered and established as my invention, be they placed howsoever or wheresoever in the engine, and that they may be fixed or used at any required distance from or annexed to the air-vessel, or either on all of the barrels, or tubes, or cylinders, in any engine constructed for the purpose of extinguishing fire, and that my chambers or receptacles are considered to contain any number of valves which may or can be introduced; and that, by this my invention, or these improvements, access may be had separately or severally, when required for any purpose, by means of a screw or flanche screwed on to or against the chambers for the specified purpose in such case provided, or by any other more easy or ready method; and that, agreeable to this my invention or improvement, it appears clearly and shall be considered to obviate the necessity of drawing the forces, fly, fan, or opening of the air-vessel or cylinders, as necessity has occasioned in all former engines not having these improvements."

The following improvement in Mr. William Perkins' Oscillating or See-saw Pump, illustrated in Figs. 4, 5, and 6, has been credited to Mr. Joseph Bramah, between the years 1783 and 1797. The illustration, Fig. 7, is a sectional elevation, and consists of a cylindrical body A, surmounted by an air-vessel B, on to which is cast a delivery pipe. In one piece with the body is cast a suction chamber D, to which the suction pipe E is bolted. The suction chamber top is provided with two rectangular suction valves F F of the clack type. The piston C is of a rectangular shape, oscillating on the centre spindle H; the piston is fitted with two rectangular delivery clack

valves J J. A diaphragm K divides the lower part of the cylinder into two separate chambers.

FIG. 7.



In pursuing his researches, the author met with the Bucket and Plunger Pump. This pump is simply an ordinary bucket lift with its pump-rod one half the area of the bucket. Some say that this pump was the invention of Mr. Smeaton, the great English Hydraulic Engineer, who was born in the year 1724, and died 1792. Another authority attributes it to a plumber, who being asked advice about a hand pump very hard to work and the pump-rod springing, commencing his operation in the orthodox fashion and to avoid the springing of the rod made it larger in diameter. Imagine his surprise, and no doubt joy, when he beheld the novel sight of water

flowing away at both up and down stroke. The plumber, being an intelligent man, made the rod larger and larger, till he obtained equal delivery at the up and down stroke. I hope this is true, for then the invention is of English origin. Our Gallic friends have a version also, and as two sides are worth having, we will give no less authority than Arthur M. Morin, the great and justly celebrated French Hydraulic Engineer. He says, in his book 'Des Machines et Appareils destinée a l'élévation des Eaux,' "The idea of placing in one and the same pump barrel two pistons of different diameters, with only one rod, or the diameters equal or nearly so, with two separate rods, is already very ancient."

"We find also, in the 'Theatrum Machinarium' of Leupold, the description of one type of this class, in which the diameter of the two pistons are different, usually calculated in the fashion that the area of the larger one is double that of the lesser one; being moved by the same rod." The Leupold to whom M. Morin alludes was Jacob Leupold, who lived between 1674 and 1727; therefore it appears that it must have been invented before Smeaton's time, as he was only three years of age at Leupold's death.

Mr. Armengaud, in the seventh volume of his celebrated Industrial publication, mentions a Bucket and Plunger Pump constructed by M. Faivre, but unfortunately he does not give any date.

One of this type of pump is illustrated in Fig. 8.

In the 'Dictionary of Mechanical Science,' by Alexander Jamieson, LL.D., published in the year 1827, he gives a description and illustration of a "Plunger Pump" consisting of a wood trunk, square or round, open at both ends, and having a valve at the bottom. This pump is illustrated in section by Fig. 9.

Fig. 8.

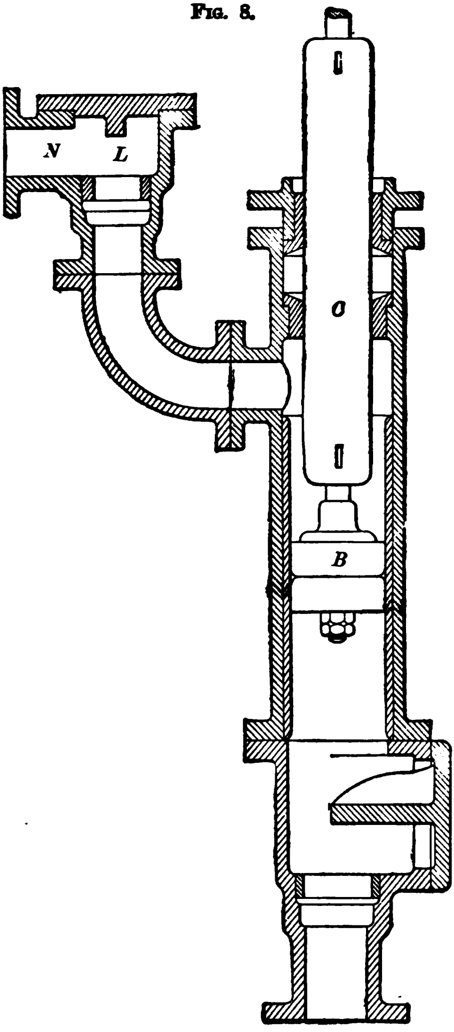
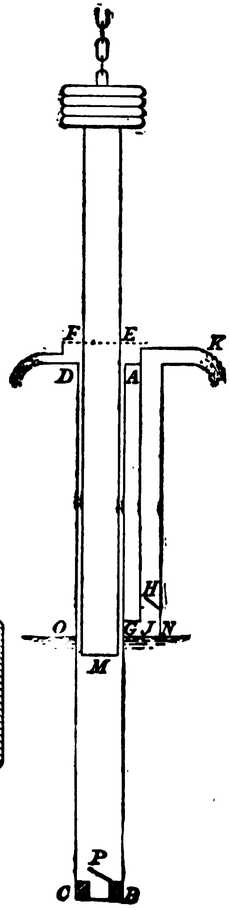


Fig. 9.



"N O is the surface of the water in the pit, and K the place of delivery. The pit must be as deep in water as from K to N O. A B C D is a wooden trunk, round or square, open at both ends, and having a valve P at the bottom. The top of this trunk must be in a level with K, and has a small cistern E F. It also communicates laterally with a rising pipe G J, furnished with a valve H opening upwards. M is a beam of timber, so fitted to the trunk as to fill it without sticking, and is of at least equal length. It hangs by a chain from a working beam, and loaded on the top with weights exceeding that of the column of water which it displaces."

Mr. Francis Trevithick, in the 'Life of Richard Trevithick,' his father, gives the following particulars:—"The increasing depth of the mines, and greater power of the steam-engines for raising water, necessitated a change in the rude pit-work, with pumps made of wood hooped with iron, having buckets with leather-cup packing and valve, which only raised water with the *upward* motion of the rods. Pistons without valves, similar to those used in steam-engines, worked in brass or iron pump-barrels, forcing the water upward with the *downward movement* of the pump rods, reducing the strength and weight of the pump bucket rods by one-half. Their descending weight about balanced the ascending water, while with the valve-bucket pump the rods had to be strong enough to bear their own weight and also that of the column of water.

"The practical cause of failure of the solid piston was its liability to jamb in the pump barrel by sand or gravel, or leakage of its leather valve was apt to cause serious accident to the costly pump-rods, and even to the steam-engine."

Plunger-poles, fitted to the case, the latter having longitudinal grooves for the passage of the water, had been used

in France, but Trevithick's plunger-pole worked in an unbored pole-case, the sides of which were not touched by the pole. This pump is shown in Figs. 10 and 11. The plunger-pole was a cast-iron pipe turned on the outside, and working in a cast-iron case, the sides of which were not touched by the pole. The pole case was provided with a stuffing-box and the necessary valves. Trevithick's pumping gear was quickly appreciated, and during the succeeding four or five years, many of the principal mines in Cornwall had their old bucket lifts removed to make room for the new plunger-pole lift. This form of pump is still largely used, almost as he designed it in 1797. Fig. 10 is a longitudinal section; Fig. 11 a sectional plan. A, is the plunger-rod of wood, fastened into the hollow cast-iron pole; B the pole or plunger; C the pole-case allowing space for the passage of water round the pole; D the stuffing-box; E the bottom valve, or suction valve, allowing the water to ascend into the pole-case, on the ascent of the pole; F the top or delivery valve, through which the water is forced upward on the descent of the pole.

FIG. 10.

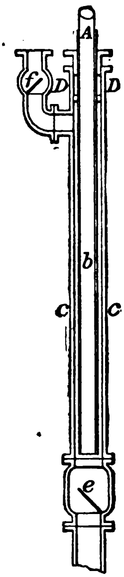


FIG. 11.

"The plunger-pole, made useful in the Cornish mines by Trevithick, met all the requirements: raising the water by the descending pump-rods, having greater simplicity of structure, and freedom from breakage or liability of jambing. The great value of this invention or application is proved by its continued use in pump-work, precisely as erected by Trevithick in 1797."

"Among other things Murdoch proposed," says Mr. Enys, in a paper "On the Cornish Engine," read by him and published in the 'Transactions of the Institute of Civil Engineers,' vol. iii., "the use of Sir Samuel Morland's plunger-pump in the pit-work, not as a general substitute but as an addition to the lifting pump, in order to suit the double-acting engine, by making the pump double-acting also. In 1796, one of these was employed at Ale and Cakes, a mine now forming the eastern part of the United Mines."

Murdoch, or, as some authorities have it, Murdock, apparently used in Ale and Cakes Mine, a plunger-pole to suit the particular requirements of Watt's double-acting engine. Trevithick's account, commencing in the following year (1797), deals with plunger-pole pit-work, not as a makeshift, but as a principle on which pit-work in a mine should be constructed. He removed the old lifting bucket pit-work, and replaced it by the plunger pit-work in several mines, in 1797.

Mr. Francis Trevithick says:—"Probably neither Murdoch nor Trevithick, knew of its having been patented one hundred years before, which takes from them the claim of first inventors, though the practically useful introduction rests with Trevithick."

In the year 1798, we still found them boring out the wood pumps in Cornwall.

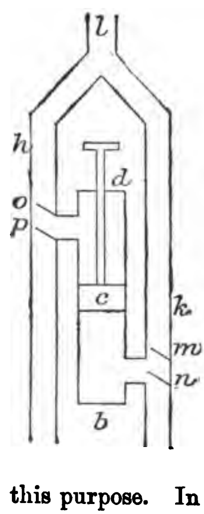
Mr. Warington Smyth, in his admirable little book, 'Coal and Coalmining,' 3rd edition, page 181, says:—"It was early found desirable, in the deep mines in Cornwall, to substitute for the buckets a forcing arrangement in all but the bottom lift. This was perfected by Captain Lean, in 1801, by the introduction of the plunger-pole or ram, working through a stuffing-box into a plunger-case of bored cast-iron, and forcing at every down-stroke, the

water upwards through an upper clack, and the clear column of pipes above it."

The following remarks will be found in the 'Treatise on the Cornish Engine,' by Mr. William Pole:—"When Captain Lean was manager of Crenver Oatfield Mines, to which he was appointed in 1801, he there first introduced the use of the plunger-pump, to supersede the lifting pump, wherever he found it practicable; that it was ultimately brought into general use, and is now become a system in the Cornish mines, the whole of the pumps in the shaft being of the plunger description, except the lower lift."

In 1809, we find the first Patent for a "Rotative pump or Engine for raising and forcing Air, Water and other Fluids," but unfortunately in this case, as in several others, no specification was enrolled. It was patented by Mr. Thomas Herbert, of Port of Malden.

FIG. 12.



We now come to the double-acting piston pump. We have found in the 'Dictionary of Art and Sciences,' by G. Gregory, D.D., second edition (no date of publication), from which we take the following description and illustration, Fig. 12:—"It is of considerable importance, that as equable motion as possible is produced in the main pipe which diminishes those strains which it is otherwise liable to." The application of an air-vessel at the beginning of the pipe, answers this purpose. In great works, it is usual to effect this by alternate action of two pumps. It will be rendered still more uniform, if four pumps are employed, succeeding each other in

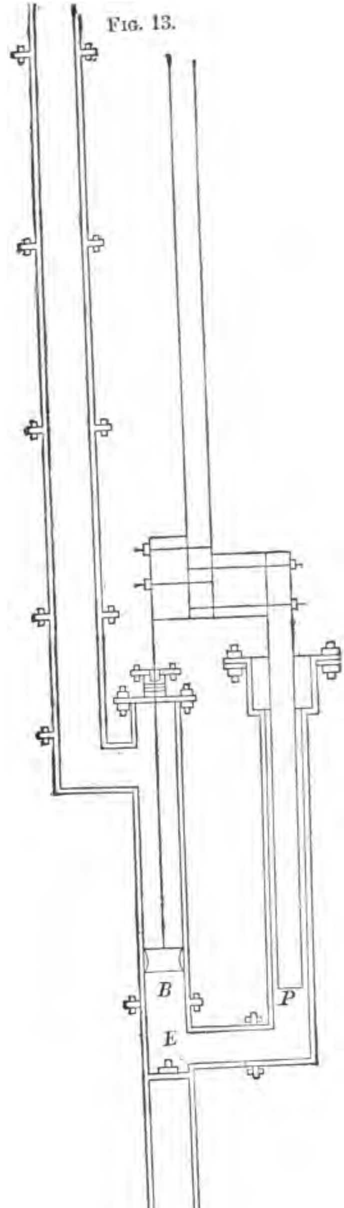
the interval of one quarter of the time of a complete stroke.

"But ingenious men have attempted the same thing with a simple pump; and many different constructions for this purpose have been proposed and executed." Fig. 12 represents one of the best, which was patented by Mr. John Morton, the 13th of August, 1807. "It consists of a working barrel *d b*, closed at both ends; the piston *c* is solid, and the piston-rod passes through a collar of leather at the top of the barrel. This barrel communicates laterally with two pipes *h* and *k*, the communication being as near to the top and bottom of the barrel as possible. At each of the communications are two valves opening upwards. The two pipes unite in a larger rising-main at *l*, which bends a little back, to give room for the piston-rod. Suppose the piston down close to the entry of the lateral pipe *k*. When it is drawn up, it compresses the air above it, and drives it through the valve in the pipe *h*, whence it escapes through the rising-pipe, at the same time it rarefies the air below it. Therefore the weight of the atmosphere shuts the valve *m*, and causes the water in the cistern to rise through the valve *n*, and fill the lower part of the pump. When the piston is pushed down again, the water is first driven through the valve *m*, because *n* immediately shuts; and then most of the air which was in this part of the pump at the beginning, goes up through it, some of the water coming back in its stead. In the mean time, the air which remained in the upper part of the pump after the ascent of the piston, is rarefied by its ascent; because the valve *o* shuts as soon as the piston begins to descend, the valve *p* opens, the air in the suction-pipe *h* expands into the barrel, and the water rises into the pipe by the pressure of the atmosphere. The next rise of the piston must bring more water into the lower part of the barrel,

and must drive a little more air through the valve *o*, namely, part of that which had come out of the suction-pipe *h*; and the next descent of the piston must drive more water into the rising pipe *k*, and along with it, most, if not all, of the air which remained below the piston, and must rarefy still more of the air remaining above the piston; and more water will came in through the pipe *h*, and get into the barrel. It is evident, that a few repetitions will at last fill the barrel on both sides of the piston with water. When this is accomplished, there is no difficulty in perceiving how, at every rise of the piston, the water of the cistern will come in by the valve *n*, and the water in the upper part of the barrel will be driven through the valve *o*; and in every descent of the piston, the water of the cistern will come into the barrel by the valve *p*, and the water below the piston will be driven through valve *m*; and thus there will be a continued influx into the barrel through the valves *n* and *p*, and a continued discharge along the rising-pipe *l* through the valves *m* and *o*."

The next allusion to a double-acting pump we found in 'Gregory's Mechanics,' published 1806:—"Temporary forcer, for a pump, is a contrivance to produce a constant stream. A very simple forcer of this kind has been devised by Richard Trevithick. This pump was invented in 1797," and is illustrated in Fig. 13. "It consists in fixing a barrel with a solid piston or plunger P, along the side of a common pump B, in such a manner that the lower space of the additional barrel may communicate with the space between the two valves of the pump, and lastly, by connecting the rods so that they may work together." The effect is, that when the pistons are raised, the space beneath the bucket B and plunger P, becomes filled by the pressure of the atmosphere at the same time that the upper column flows

FIG. 13.



out. But again, when the pistons descend the valve E shuts, and consequently the water driven by the plunger P must ascend through B, and continue to produce an equal discharge in the upstroke.

M. Jorge, in 1816, submitted to the French Academy of Science, a species of centrifugal pump of the principle of the ordinary fan for blowing air, but the first approach to the present form of centrifugal pumps was made in Massachusetts, United States, in the year 1818, under the title of Massachusetts pump, and was re-invented by Andrews and various other persons. This pump received the water equally on both sides at the centre, and discharged it at the periphery, the case gradually enlarging as the water approached the delivery pipe. There were four straight vanes, not placed radially but parallel with the radius, and they were narrowed towards the tip. The vanes were not, however, enclosed within a revolving case, but revolved nearly in contact with the sides of the fixed case.

We now come to a class of pump which for many years was almost exclusively used for the ships in the British Navy. It was invented and patented by Mr. Jonathan Dounton, of Blackwall, London, in the year 1825. It is illustrated in Figs. 14 and 15. Fig. 14 is a sectional elevation and Fig. 15 a front view. A is the suction-pipe, B the suction-valve, C the working barrel, and D the delivery pipe. It will be seen that there are three movable valves or buckets in the working barrel; of these three buckets, F is the lower one, G the middle one, and H the upper bucket, and the object of having three buckets is that one at the least may be always rising, and this is done by the following arrangement:—By the bucket rods working one within the other, with a telescope movement. Thus it will be seen by reference to the illustration, that the bucket rods for G and H are hollow, and that the rod

Fig. 14.

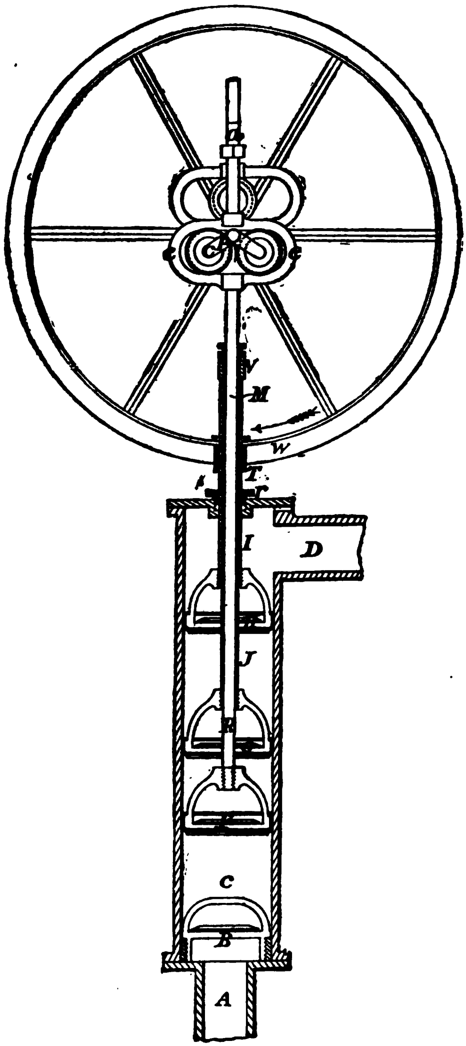
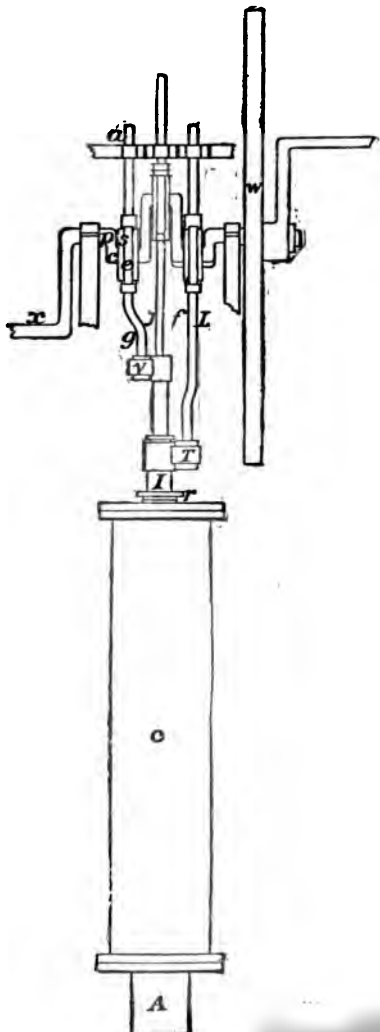


FIG. 15.



R of the lower bucket F, works within the rod J of the bucket G, and this last-mentioned rod works within the rod I of the bucket H; this arrangenent allows the up and down movements of each rod to be performed without the slightest impediment from or interference with the others; it only remains, therefore, to connect these rods to such a movement as will cause one or other of them to be constantly on the rise, and a continued stream of water flowing from the delivery pipe must be the consequence; such a movement is shown in the illustrations:—W is a fly-wheel, *a* is the top of the rod J, and is furnished with a hoop or slot *e*, *e*, within which the friction wheel S revolves; P is an arm of a three-throw crank, of which the part marked C forms the axis of the wheel S. Now it is evident that as this wheel S revolves by the turning of the crank P, it will alternately raise and depress the rod J, and its bucket G. It is only necessary to observe, in further explanation of the illustrations, that each rod head is furnished with one of these hoops or slots, and with a friction wheel within it, moved by and turned on a crank arm, and it is the position of these crank arms which determines the exact nature of the alternate and relative up and down movement of the three rods and their respective buckets. T, V, are parts better explained by Fig. 15; T is the mere collar or busking, or what would, in a large pump, be a stuffing-box.

Fig. 15 is an elevation of one of these pumps; the letters in the two figures refer to the same parts. T is a clamp or arrangement for attaching the solid rod *f*, L, to the hollow rod I, in order to connect it with the crank wheel and slot movement above it; and V is a similar contrivance for attaching the solid rod *g*, J, to the hollow rod J, for a similar purpose; X is a crank for giving a winch movement, and by which movement the pump is to be worked. Now it will be observed from the position of these three cranks,

that in the position shown, the crank P, which governs the movement of the rod J, recedes, while the crank which governs the movement of the rod I advances, and the crank which governs the movement of the rod R is in its highest upward position; it follows, therefore, that if the winch X were turned so as to turn the fly-wheel in the direction of the arrow, the rod J would be raised, while the rod I would be depressed and the rod R, which in this view has attained its greatest elevation, would begin to be depressed; also, if the motions which must necessarily follow a continuation of the revolution be traced, it will be found that at the moment the rods J and I arrive at that point where they must remain for a moment nearly inactive, the rod R will be rising and thus the continuity of the stream will be preserved.

A hollow ram-pump is described in 'Dictionary of Mechanical Science and Art,' by Alexander Jamieson, published 1827.

"It is easy to see that the suction-pump may be varied. Supposing this plunger to be open both at top and bottom, but the bottom fitted with a valve opening upwards. When this is pushed to the bottom of the barrel, the air which it tends to compress lifts the valve, and escapes through the plunger. When it is drawn up, it makes the same rarefaction as the solid plunger, because the valve in the plunger shuts, and the water will come up from the cistern as in the former case" (referring to the description of the ordinary plunger pump). "If the plunger be now thrust down again, the suction-valve will shut, the valve in the plunger is forced open, and the plunger is filled with water. This will be lifted by it during its next ascent; and when it is pushed down again, the water which filled it must now be pushed out, and will flow over its sides into the cistern at the head of

the barrel. Instead of making the valve at the bottom of the piston, it may be made at the top; but this disposition is much inferior, because it cannot rarefy the air in the barrel one-half. This is evident, for the capacity of the barrel and plunger together cannot be twice the capacity of the barrel.

Fig. 16.

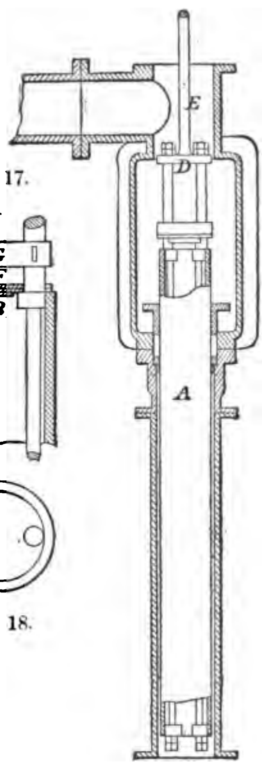
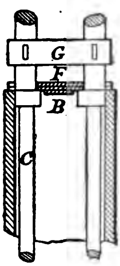


Fig. 17.



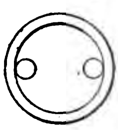


Fig. 18.

A pump of this description is illustrated in Figs. 16, 17, and 18. Fig. 16 is a sectional elevation; Fig. 17, an enlarged view of the top of the plunger; and Fig. 18, the plan of the delivery valve.

The plunger-case is similar to the ordinary one, and fitted at the top with a stuffing-box and gland; to the top of the stuffing-box is secured a delivery clack-piece furnished with a door for access to the delivery valve, and to the top of this clack-piece is bolted a cover provided with a stuffing-box and gland for the pump-rod (not shown in the illustrations).

The plunger consists of a hollow pipe A, without flanges, turned all over perfectly true and parallel; it is

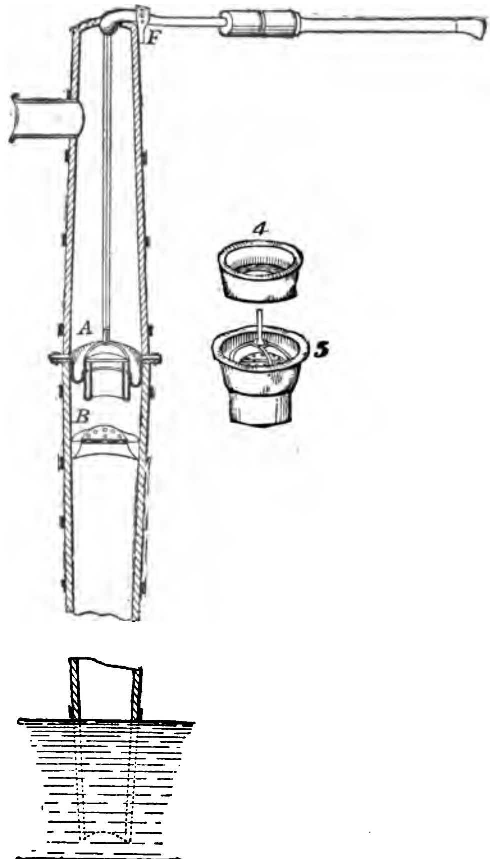
furnished at top and bottom in the inside with two lugs B, through which pass two wrought-iron rods C, provided at the bottom ends with double nuts, and at top secured to a cross-piece D, forged on the main-pump rod E, and secured by double nuts.

The delivery valve F, in this example of hollow ram or plunger-pump, is simply a round disc sliding on the two plunger-rods C, the disc being faced with leather, and a cross-piece G, secured to the plunger-rods C, by cotters, is provided for determining the lift of the valve.

A rather peculiar type of single-acting pump was patented in the year 1828 by Mr. William Spalder, of Norwich. It is described and illustrated in the 'Mechanic's Magazine,' volume 8, page 438, year 1828, in the following manner:—"The illustration, Fig. 19, is a sectional elevation. A is the upper valve; B the lower valve; F the fulcrum for the pump handle; 4 is the connector blocked; 5 the connector and expresser. If the reader will keep in his mind's eye, that at equal altitudes fluids press in all directions alike, he will see that in Fig. 19, which is influenced by rarefaction, the connector is kept in its right position by the downward pressure of the fluid. The connector being of a superior gravity to water, descends with the expresser in that fluid. The expresser, when rising, acting as a mast does to a sail, guides and supports the connector, which presses the side of the fluid to the centre, as *nature directs*, and raises a weight on a wheel turning on a fluid axis with a *rolling motion*. Again, the piston slides the fluid in a compact form, as though it were a solid—a course that fluids at liberty never pursue. The united power of all the steam-engines in use, would be inadequate to violate the course of Father Thames in like manner, and compel him to move at the bottom, centre, and the surface, with equal velocity

More to the point: did not fluids abhor sliding against tubes, would mercury rise with a convex, and fall with a concave head in changeable weather? And, upon this

FIG. 19.



ground, will the fountain overmatch that very refined machine, the quicksilver pump?" The inventor of this pump has given it the name "Gravitating Expressing Fountain."

In 1831 Mr. Blake introduced a centrifugal disc pump, with vanes on the one side of the disc only, while the other was smooth. The vanes gave rotatory motion to the entering water, which drove it to the periphery of the case, where it overflowed the edges of the disc to the smooth side, and through a pipe attached to the case on that side of the disc the water escapes.

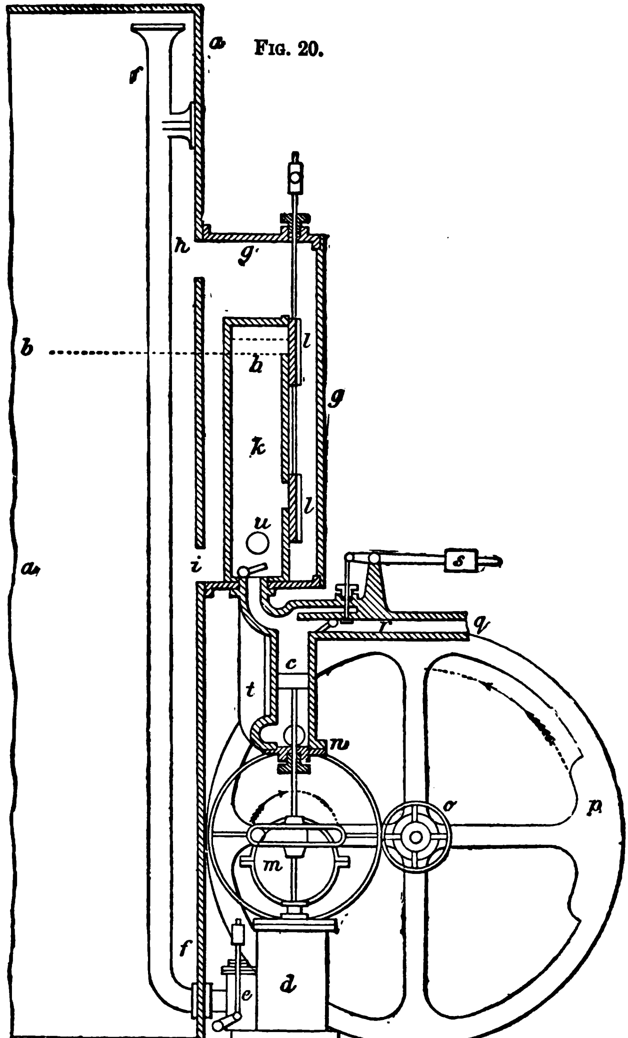
In the year 1838 an American centrifugal pump was erected at the New York Navy-yard; the pump had curved vanes, but these, curiously enough, were discarded and straight vanes put in.

Between the years 1838 and 1843, M. C. H. Combes advocated curved vanes, which a discussion of a paper read by him, and subsequent trials with models, confirmed.

A vertical double-acting piston pump is illustrated in 'Mechanics' Magazine,' May 5th, 1838, coupled to a steam cylinder. As this is the oldest record of an independent feed pump the author has met with, he will give the description and illustration, Fig. 20, in full.

"Plan for keeping the boilers of high-pressure steam-engines always filled with water up to the required level, both when the engines are working and when they are not at work; together with directions how the plan may be applied to the boilers of condensing engines." "*a a* in the figure (Fig. 20) shows a section of one end of a high-pressure boiler, and the dotted line *b b* is drawn near to the place at which the water in it should stand. The feed pump *c* is wrought by means of a small steam-engine, the cylinder, nozles, and steam-pipe of which are marked

FIG. 20.



by *d e*, and *f f*, respectively. *g g* is a casing fixed upon this boiler, *h* and *i* are holes which allow the water always to stand at the same level in the casing as in the boiler, and these holes diminish the agitation which the water in the casing would have if the whole of one of its sides was open into the boiler. Inside of the casing a chest *k* is fixed, having a space left round its sides and top for the steam and water to get past it freely. The chest *k* has two openings or ports in one of its sides, with one of the valves marked *l*, working upon each in such a manner as that the inside of the chest has no communication with the casing *g g*, during the time the piston of the feed-pump is working upwards; but when the piston of this pump is working towards the cylinder *d*, then there is always a communication with the chest *k* and the casing. A pulley upon the crank-pin of the little engine works into a horizontal slit in a frame fixed upon the top of the piston-rod, and the bottom end of the rod of the feed-pump is attached to the top side of the same frame; in this way the crank-shaft as well as the feed-pump are set in motion. The eccentric *m*, which works the valves *l l*, is fixed upon the crank. Both of the valves marked *l* are attached to the same rod, or, in order that the eccentric *m* may stand right under them, the steam cylinder *d* and the feed-pump are placed a little towards one side of the boiler, while the casing *g g*, and the chest *k*, stand toward the other side. The fly-wheel is on the second motion, and its shaft is driven by means of the spur-wheel *n* and the pinion *o*, so as to make double the number of revolutions of the crank-shaft. As the fly-wheel makes two revolutions for one of the crank-shaft, its heavy side *p* will always be next the end of the boiler, and in a line level with its own shaft, every time the piston is at the top or bottom end of its stroke; by this arrangement (if the parts work in the direction of the arrows, and if the fly-wheel has the

position on its shaft, as per the figure), the engine can never stand on its centres, however slow its motions, as the heavy side of the fly-wheel will always be in a position to carry it past them. The slide valves *l l*, must be fitted upon the chest *k* in such a manner that they will not be forced away from their faces when the pressure inside the chest is greater than the pressure in the boiler."

"When the piston of the feed-pump arrives at the top end of its stroke, as then a pump-full of water has passed into the chest *k*, the steam in the top part of the chest will be compressed, and on this account it will have a greater pressure than the steam in the boiler; and if the space in *k*, which lies above the surface of the water in the boiler, is twice as large as the contents of the pump-barrel, then when a full of the pump is sent in *k*, the steam in it will be of twice the density of the steam in the boiler. If the space in *k*, which lies above the dotted line *b b*, is double that of the contents of the barrel of the feed-pump, then the conical valve *r* must have its weight *s* so heavy as that it will allow the valve to open as soon as the pressure inside of the chest *k* is double of the force of the steam in the boiler. If the steam space in the chest *k* holds twice the full amount of the pump-barrel, and if the valve *r* is loaded to the extent now mentioned, a pump-full of water will pass into the boiler after each stroke, as soon as the valves *l l* are opened, whenever the water in the boiler stands at or under the dotted line *b b*, as in this case the pressure inside of *k* will not have opened the valve *r*, and allowed part of the contents of the feed-pump to be discharged back into the hot-well of the large engine; but if the water in the boiler stands above the line *b b*, then (as by this the steam space in *k* is diminished) the pressure inside *k* will open the valve *r* before the pump has finished its stroke, and allow part of

the water to escape through the communication, running betwixt the top of the pump and a part of the pipe *q* (behind its valve), leading to the hot-well. So by this contrivance, whenever the water in the boiler stands so high as that the steam space in *k* is not double that of the contents of the pump-barrel, then a portion of the water in the pump will be sent through the valve *r* back into the hot-well, and when the valves *l l* are opened there will not be a barrelful of water in *k* to pass into the boiler. The more the steam space in *k* is diminished by the water rising in the boiler, a less quantity of the water from the feed-pump will pass into *k* at each stroke, and on this account the boiler will always get less water from the feed-pump the higher the water stands in it above the line *b b*. If the water in the boiler stood as high as the chest *k*, then no water could pass into it from the pump. When the water in the boiler is low, and on this account the steam space in *k* is made as great or greater than double the contents of the feed-pump, then a pump-full of water will pass from the chest *k* into the boiler every time the valves *l l* open. In this way, if the boiler is too full, it gets less feed than its average quantity at each stroke of the pump; and if there is not enough of water in it, it is supplied with more than the average quantity; and for this reason the water in it will keep always at the same level."

"It is to be understood that the feed-pump is double-acting, and in its downstroke the water is discharged through the pipe *t*, into a chest placed alongside of the chest *k*, and of the same dimensions. This chest is also to have valves working in it, like those marked *l*. The small circle at the bottom of the feed-pump shows the pipe which leads the water into it; the pipe at the bottom of the pump for this purpose should have been drawn

running in the same direction as this one, if it had not been wanted to show the loaded valve *r*, &c. I have not shown the loaded valve at the bottom of the pump, as it and the other part are of the same construction as shown for the top end.

"It is not important that the space which is above the line *b b* in the chest *k*, is double of the contents of the feed-pump; only if this space is made in any other proportion to the contents of the pump, the weight *s* must be made to correspond to it. I may here remark that the additional pressure given to the steam in the chest *k*, by the water pumped into it, helps the water to pass from the chest into the boiler as soon as the valves *l l* open.

"By having the cylinder *d* and the nozle *e*, as well as the feed-pump, pretty large, the small engine will not require more steam to work it than if these parts were made small, as in this case it will work slow when it is forcing the water through the loaded valve *r*, if this valve is fitted so that it can only open a small distance. From the manner in which the fly-wheel is applied to the engine, it cannot stop, although its motion is not a quick one.

"When two boilers are to be supplied with water by means of a small engine with one feed-pump, then the chest *k*, and the other parts in connection with it, must be fixed upon one boiler, and the other chest of the same sort as *k*, and which is in connection with the bottom end of the feed-pump, must be fixed to the end of the other boiler. If four boilers are to be supplied with water by means of a small steam-engine and one feed-pump, then a chest, as *k*, and its appendages, must be fixed upon each boiler, two of them in connection with the top end of the pump, and the other two in connection with the bottom end. If two or more chests, like *k*, are connected to the same end

of a pump, then the pipe passes from the pump to one of them, and a pipe, as the one at *r*, connects the others of the set. On the principle now explained, any number of boilers may be supplied with water by means of the same feeding apparatus. Only one loaded valve to the top of the pump, and another to the bottom are required, whatever may be the number of boilers to be fed.

"The pump, for an apparatus as now described, may be wrought by the large steam-engine in the ordinary way, if the loaded valve is very large, and if it is made to open sufficiently, in the case the pump be single-acting, and only one chest like *k* will be required. If the feed-pump is wrought as now described, the boiler will get no water when the large engine is standing. When the feed-pump is wrought by the large engine, then a ratchet should be connected to the lever of the loaded valve, so as to work a screw in order to shorten the stroke of the pump a little every time the valve opens; and a similar motion should be taken from the engine to lengthen the stroke of the pump at any time the valve *r* did not open.

"If an apparatus, as already described, is to be put upon the boilers for a low-pressure steam-engine, then the small engine which works the feed-pump must have an air-pump and condenser to it. The only difficulty attending this arrangement is the following:—When the boiler is very full of water, and the escape at the loaded valve *r* is small, then the small engine will work slow, and on account of this too much water will run into the condenser. This inconvenience can be got over by causing the injection cock to shut as soon as the engine is longer than a certain time in making a revolution. A cam or tooth fixed upon the crank-shaft of the little engine. so as to lift the piston of a common cataract at each revolution, will answer the desired end; for if the piston-rod of the

cataract is connected to the handle of the injection cock by a proper arrangement, then if the engine is longer than a certain time in making its revolution, the cataract will shut the injection cock, and it will remain shut till the cam fixed upon the crank shaft acts upon the cataract and opens it. In this way the exact quantity of water required to condense the steam can be let into the condenser at each stroke.

"The arrangement of the parts, as per the Figure, is for a steamboat boiler. In a boiler with a building round its end, the chest *g g*, and the other parts of the feeding apparatus, must be placed at a distance from it; and pipes run from the chest and join the boiler at the holes *h* and *i*. In order to avoid complexity, the framing which supports the fly-wheel shaft, as well as some of the other parts, are not put into the Figure. The short dotted line running above the line *b b* is intended to show the height at which the water stands in the chest *k* after a full of the pump is put into it.

"As in ordinary cases the common feed-pump will not be wanted, if the feeding apparatus as now described is used, the addition to the cost of a new engine will be trifling, and it is a very great advantage to have boilers (especially high-pressure ones) regularly supplied with water.

"I am, Sir, yours truly,

"JAMES WHITELAW.

"London, April 12th, 1838.

"P.S.—The steam space in the chest *k* may be made of the same capacity as the barrel of the feed-pump, if the pipe, or communication, which carries the water back to the hot-well of the large engine runs, not from the end of the pump, but from the top of the steam-space to the same place in the pipe *g* as shown in the Figure. In this plan

the steam is not compressed into the chest *k*, but it is sent into the hot-well of the large engine at each stroke, and the waste water passes along with it. The loaded valve must be made to open with a force not much greater than that of the steam in the boiler, in this case; or a valve, made to open and shut by means of an eccentric, will answer instead of the valve *r*. The remarks made in this paragraph apply when there is only one chest to each end of the pump; when there is a number of chests in connection with each end of the pump, the same remarks apply if their united capacity is equal to that of the feed-pump."

Mr. G. Whitelow, a Scotchman, again tried the idea of reversing the Barker's Mill for pumping, in 1841; they gave 77 per cent. duty, but, being not so cheap and convenient for most purposes, were discarded.

A patent was granted, January 11th, 1842, to Mr. J. T. Jeffree, for a pump fitted with a slide valve. This is described and illustrated in 'Mechanics' Magazine,' volume 37, page 146.

"To the side of the barrel of the pump, he affixes a plain-surfaced piece of wood or iron, of an oblong form, as represented by Fig. 21 in the accompanying engravings,

FIG. 21.

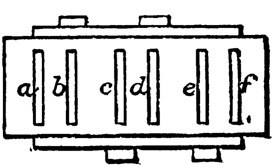
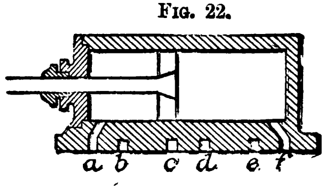


FIG. 22.



having six rectangular apertures, *a*, *b*, *c*, *d*, *e*, *f*, communicating with different passages made through the body of the said piece, and represented in the sectional

views, Figs. 22 and 23. The apertures *a* and *f* communicate with passages which lead into the barrel of the pump, one on each side of the piston, as shown in the horizontal section, Fig. 22; the openings *b* and *d* lead upwards to the discharge-pipes, as shown in the vertical section, Fig. 23; while the apertures *c* and *e* lead down-

FIG. 23.

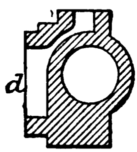


FIG. 24.

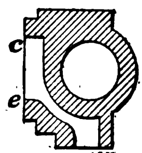
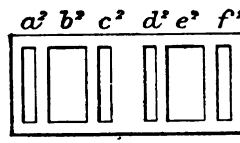


FIG. 25.



ward to the well or other source of supply, as represented in the sectional view, Fig. 24 (the discharge and supply pipes being omitted in the engravings, as unnecessary to a clear comprehension of the invention). To the plain-surfaced piece, Fig. 21, is adapted another plain-surface piece, Fig. 25 (the two pieces being ground true, to fit each other exactly), and having six rectangular apertures, a^2, b^2, c^2, d^2, e^2, and f^2, leading to passages in the said piece, Fig. 25, which communicate with each other in the manner shown in the horizontal section, Fig. 27. To the outside of this piece, Fig. 27, is attached a rod, which rod is parallel to the piston-rod, and moves to and fro simultaneously with it, and by the same power, whatever that may be. The better to preserve the parallelism of the piece 25, it may be made to slide within flanges raised on the face of the piece,

FIG. 27.

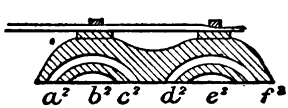


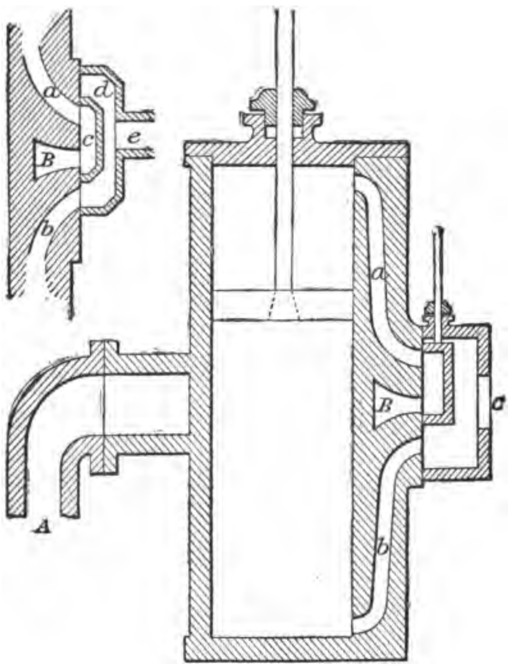
Fig. 21; but when the pump is short, this is not thought to be necessary.

"The action of the pump is as follows:—Suppose the piston is at the bottom or farther end of the barrel, the two pieces, Figs. 21 and 25, will then be face to face, or in full contact, and the apertures and solid parts of the two faces will be in such relative positions to one another, that one of each of the three pairs of apertures, the pair leading to the barrel (*a* and *f*), the pair leading to the discharge-pipe (*b* and *d*), and the pair leading to the well or other source of supply (*c* and *e*), will be open, and the other shut. The piston being now raised or drawn out, the vacuum produced causes the water to flow up from the well or other source of supply, through the aperture *e* in the face of the piece, Fig. 21, into the aperture e^2 in the face of the piece, Fig. 25, whence it passes through the aperture *f*, Fig. 21, into the barrel of the pump; by the return stroke of the piston, the water which was raised by the preceding stroke is expelled from the pump-barrel, through the apertures *f* and *d*, into the upward discharge-pipe connected with the opening *d*; while, at the same time, the vacuum produced behind the piston causes the water to flow up from the well or other source of supply, and pass through the apertures *b* and *a* into the barrel, ready to be discharged at the next up or outward stroke of the piston. At every subsequent stroke of the piston there will, of course, be always one body of water supplied to the pump-barrel, and one discharged from it, and that alternately at opposite ends of the piston; and if the discharge-pipes connected with the openings *b* and *d*, are made to empty themselves into one common mouth-piece, the water will be discharged in one continuous stream.

"A pump of this sort is obviously liable to no other

derangement than what may occasionally arise from some of the apertures being obstructed; but in that case the evil can be at once got at by simply taking off the upper piece, Fig. 25, and when the obstruction is removed, the pump becomes as good as ever.

FIG. 26. FIG. 28.



"Another plan of construction, more nearly resembling the slide-valve used in steam-engines, and which might, in fact, be advantageously substituted for it in many instances, as it would do away entirely with the ordinary jacket and stuffing-box, is shown in Figs. 26 and 28.

"Fig. 28 shows the pump as it should be if fitted with a slide-valve of the ordinary construction; and Fig. 26, shows the sort of valve which the patentee proposes to substitute for it. In a pump of the construction Fig. 28, the water rising in the pipe A flows by a curved passage carried round the barrel of the pump to the opening B, whence it passes upwards, through a channel *a*, left open by the slide, into the barrel; whilst, at the same time, the water supposed to be left in the lower part of the barrel by the preceding stroke is forced up the passage *b*, and into the casing of the slide, whence it is discharged through the orifice C. The improved slide-valve, represented in Fig. 26, *is all in one piece*, and of an oblong form, with a plain face, but curved a little if necessary, so as to fit exactly to the barrel of the pump. In the centre of the face there is a recess, *c*, of sufficient width to cover the two passages *a* and B, and behind it there is a curved channel *d*, cut out in the body of the slide, lengthwise, and terminating at top and bottom in apertures in the face of the slide, which, as the slide is moved up and down (by parallel connectors with the piston-rod, in the usual manner) communicate alternately with the passages *a* and *b*, allowing the water to flow through *c a*, up into the pump barrel, and through *b d* into the discharge-pipe *e*."

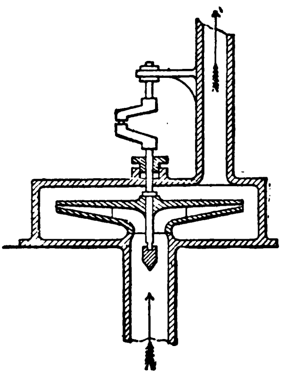
Great have been the modifications of the hollow ram-pump, but the most peculiar we have met with is perhaps the one patented by Mr. Thomas Heaton in the year 1844. This pump is a combination of the hollow ram-pump and the bucket and plunger pump, with a very deep bucket.

Mr. Heaton claims as features of novelty: first, the application of a hollow ram or plunger, which may be of an equal area with the working barrel. This application of a hollow ram or plunger to pumps for raising and forcing water and other fluids, is for the purpose of

displacing a considerable quantity of the fluid above the bucket, as the bucket descends; and by the removing of the weight of fluid above the elongated bucket, greatly economising the strain upon the working machinery of the primary moving power.

His second improvement being that of using two suction-valves, and two valves in the elongated bucket, so that if one valve is disabled, the other may be working.

FIG. 29.



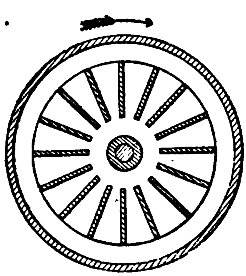


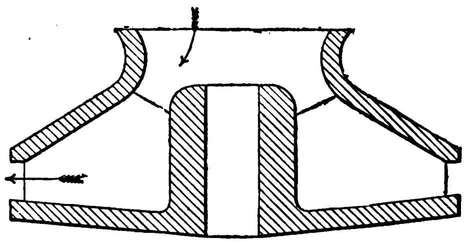
FIG. 30.

Mr. Bessemer, in the year 1845, introduced centrifugal pumps of various forms, one of which is illustrated in Figs. 29 and 30; it resembled the Blake pump, introduced in the year 1831. This fan is distinguished by numerous radial blades enclosed between discs converging towards the outer periphery, and by a suction orifice, with arrangement for taking, upon an adjustable pivot, the unbalanced weight of the column of water, tending to press the fan against the suction-pipe.

In 1846, Andrews patented a centrifugal pump, which had a revolving disc on each side of the vanes, as in Lloyd's fan, and which had four curved vanes, illustrated in Figs. 31 and 32. Mr. Andrews's pump was in regular

use in New York at the time Mr. John Gwynne bought the patent, and shortly afterwards introduced it into England.

FIG. 31.



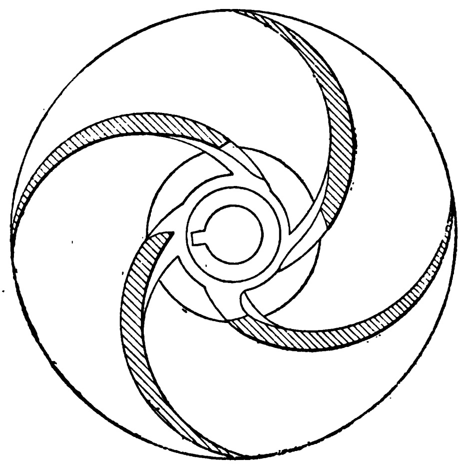
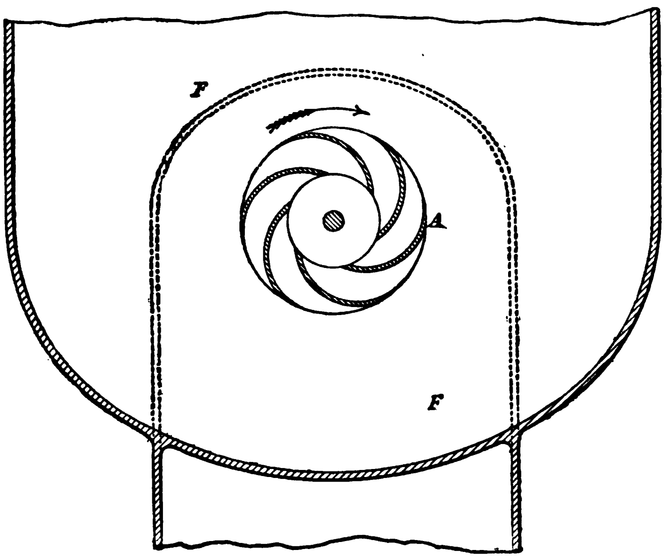


FIG. 32.

Mr. Lloyd took out his fan patent in 1848, and in the same year Mr. J. G. Appold began the manufacture of almost the same kind of fan, to be applied to the raising

of water. This pump was never patented. At the British Association meeting, held at Birmingham in the year 1849, Mr. Appold exhibited a model of a centrifugal pump. The real success of the centrifugal pump can be said to have commenced in this year. By an exhaustive set of experiments, principally directed as to the form for the fans or impellers, as they are now generally termed,

Fig. 33.

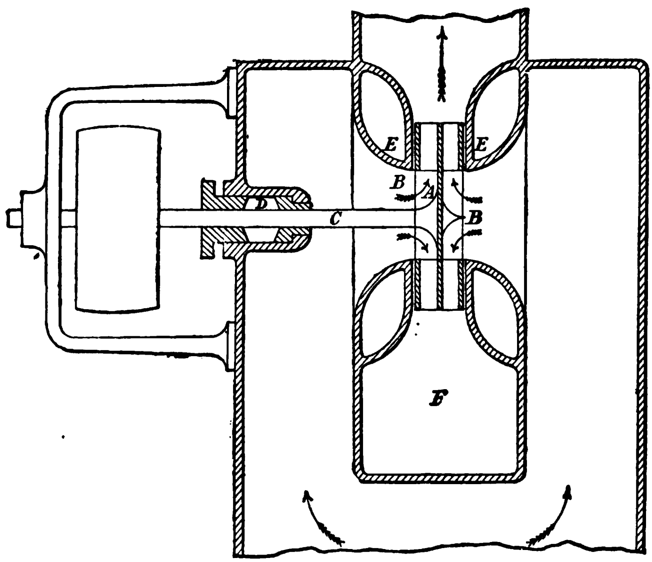


Mr. Appold gradually improved the discharging capacity, and was enabled to exhibit a pump at the Exhibition in London of 1851, which formed one of the chief features of interest, the public being astonished at the immense volume of water put in motion by a machine which

appeared both from its size and simplicity of form to be quite inadequate to the results attained.

At that time there were but few who believed in centrifugal pumps, and there can be no doubt that Mr. Appold was among the first to demonstrate their practicability in England.

FIG. 34.



Figs. 33 and 34 illustrate Appold's centrifugal pump, as shown at the Exhibition in London, 1851.

The revolving fan A, was 12 inches in diameter and 3 inches wide, having an opening one-half the total diameter in the centre of each side for the admission of the water, and a central division plate, extending to the circumference, to give a direction to the two streams of

water, and convenient for fixing on the shaft; the six arms are curved backwards, terminating nearly tangential to the circumference. The revolving fan was fixed on the end of the driving-shaft C, which passes through a stuffing-box in the side of the casing; and it works between two circular cheeks E E, running close without actually touching, whereby the outer revolving surfaces are shielded from the water, but a free ingress is allowed for the water to enter, and a large space F F is left all round the circumference of the fan, to facilitate the escape of the discharged water.

Several experiments were made by the Exhibition Jury.

In the experiments with straight arms, the revolving fan was removed, and others were fixed in its place, exactly similar in other respects, but having straight

FIG. 35.

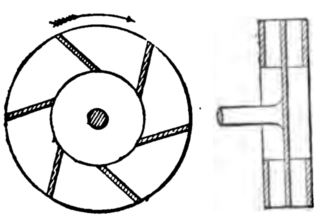
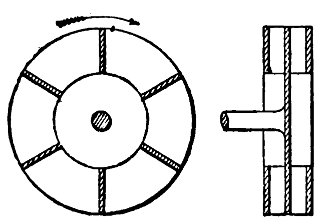


FIG. 36.



arms inclined at 45 degrees, as shown in Fig. 35, or radial as in Fig. 36, instead of the curved arms shown in Fig. 37.

The result of these experiments were:—

Straight radial arms, 20 per cent. straight inclined arms, 45 per cent.; and the average for arms or blades curved backwards, 68 per cent.

The superior action of oblique arms to radial arms

might be illustrated by supposing a vertical arm A B, Fig. 38, to move in a straight line to C D, instead of moving round in a circle in the pump; and the body A, representing a particle of water, would then be simply moved along to C, with the arm, without having any tendency to be propelled outwards along the arm to B. But if an oblique arm A E, was employed, moving in the same direction as before to the position C B, it propelled the particle A outwards towards B, having an inclined plane action to push the particles of water outwards from the centre towards the circumference. When this was applied to a circular motion, and the direction A C bent into a circle, the in-

FIG. 37.

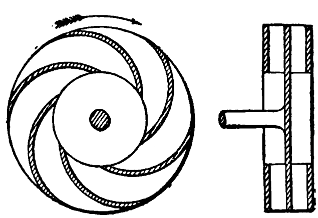
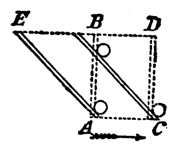


FIG. 38.



clined arm A E became curved in a spiral direction, like the arms in the pump.

One of the most peculiar pumps that has come under our notice during our researches is one patented by Mr. Robert Urwin in the year 1849; the peculiar feature being that it has only one suction valve and one suction passage to the pump-barrel, although the pump is of the double-acting piston type. This pump is illustrated in Figs. 39 and 40. Fig. 39 is a sectional elevation; and Fig. 40 a section on A B. The arrows show the direction of the flow of the water through the valves and passages.

C is the pump barrel, having a delivery passage D at each end, and a suction passage E in the middle of the barrel. F is the pump piston, G the suction branch, H the suction valve, J the delivery pipe, K and L the

Fig. 39.

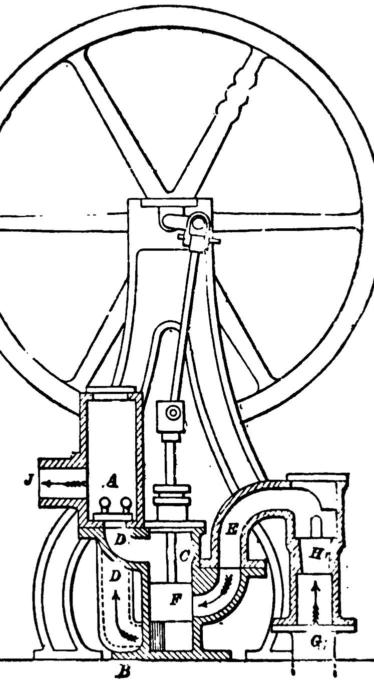
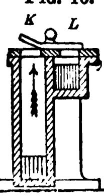


Fig. 40.



delivery valves. As the pump is represented, the piston F is in the middle of its stroke, and the piston moving downwards delivering the water through the side passage D, and through the delivery valve K; but the suction

passage E is not yet opened by the piston, which in the present position covers it. The piston must be of such depth in proportion to the length of the barrel, that, at the termination of the stroke, either way, the piston shall pass clear over the suction passage E. As soon as the piston opens the suction passage E, the water will rush in above the piston, while the piston by its continued descent will expel the water in the lower part of the barrel into the delivery pipe. On the up-stroke the reverse action will of course take place.

Up to the year 1850, the usual practice was to make the pump of the piston type, for horizontal pumping appliances; but in that year Mr. Henry Worthington, of New York, brought out his internally-packed horizontal double-acting ram or plunger-pump. This pump is shown in Figs. 41 and 42. B, is the pump plunger. It is double-acting and works through a metallic-packing, C C; D D are the suction valves, and E E the delivery valves, consisting each of a disc of indiarubber, rising on a brass spindle with a guard at the top, and falling upon a circular plate perforated with holes. In the plunger are bored a few holes H H, which have the effect of opening a communication between the two ends of the pump barrel at each end of the stroke, thus giving the water, as it were, a partial elasticity, allowing it to continue its forward motion by flowing through the plunger during the moment that the plunger becomes stationary. This enables the plunger to commence its return stroke without any shock or concussion. O is an air-vessel on the delivery branch, and P is a suction air or vacuum-vessel. A is a double-seated valve, by means of which the water can be delivered either through the pipe F or G.

Mr. John Gwynne applied for a patent of a centrifugal pump in the year 1850, but owing to a mistake made by

the patent agent, a new application became necessary, and the patent, therefore, bears date 1851. In the patent he especially distinguished the admission of water to each

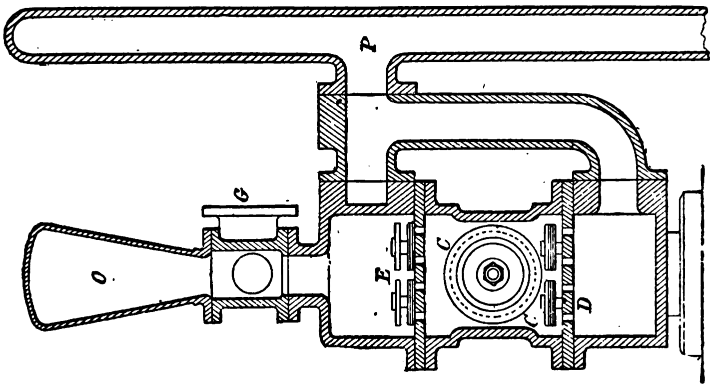


FIG. 42

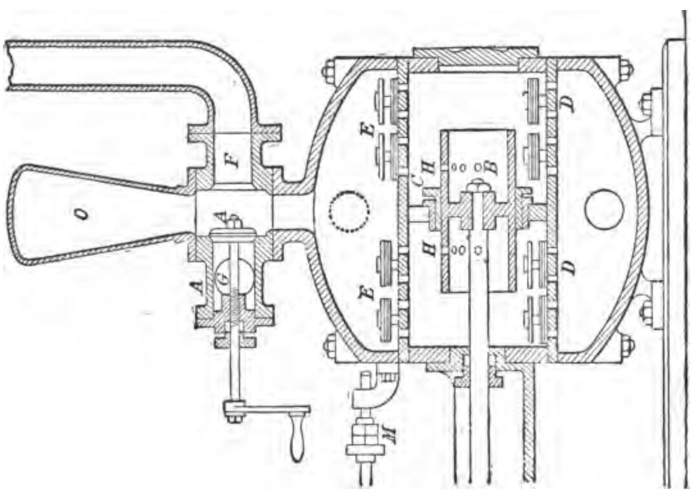


FIG. 41.

side of the pump, but although he had acquired Andrews's interest, he did not re-patent all that had been done before him. The admission of water on both sides of the centrifugal pump, as practised in the Massachusetts pump of 1881, and in later inventions, was not Andrews's nor was

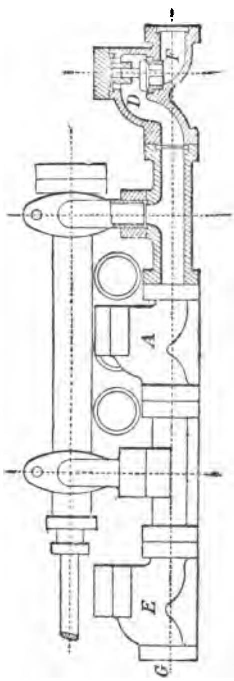


FIG 43.

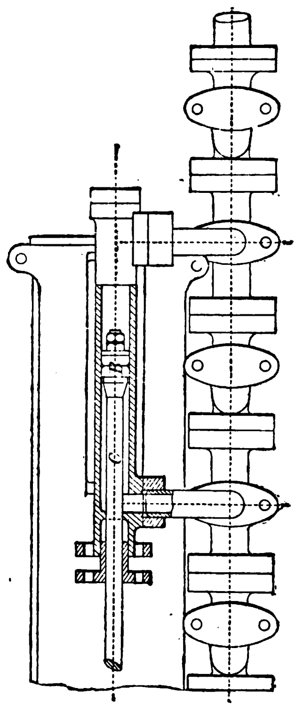


FIG. 44.

it Gwynne's, but all were free to use it, and Mr. Lloyd and Mr. Appold had already done so. Andrews's pump revolved upon a vertical spindle and discharged its water horizontally outward, so that, for moderate lifts, it did not

need the inlet upon both sides, which double inlet is always seen in the present class of centrifugal pump revolving on a horizontal spindle.

We now come to a slight modification of the bucket and plunger pump, which is called piston and plunger pump; the difference will easily be seen by referring to Figs. 43 and 44. It resembles the bucket and plunger pump, but instead of the delivery valve being fitted into the bucket, it is placed in the delivery valve-box A. B is the piston; C is the plunger and piston-rod; D is the suction-valve and box; E the retaining or back pressure valve-box; F the suction inlet; G the delivery outlet. Sir William Armstrong says, in a paper read by him in the year 1858, that "this type of pump was suggested to me, about the year 1851, by Mr. Henry Thompson, my late intelligent foreman." As the Author cannot find anything to the contrary, the honour ought to be given to Mr. Thompson, for the invention of this pump, although many have claimed to be the inventors after that date.

In 1854, Mr. J. E. A. Gwynne took out a patent of an improved form of Gwynne pump. This pump is illustrated in Figs. 45 and 46, and consists of a revolving wheel or disc, formed of two concave plates, placed parallel, with their concave surfaces towards each other. Between these discs is an arm or impeller, radiating from a boss or hollow axis mounted on a shaft, which works horizontally, vertically, or at any intermediate angle. This impeller, which regulates the distance between the discs, varies in breadth; its narrowest part is at the outer edge of the disc, becoming gradually broader until its edges intersect the inner surface of the opening for the suction. Its breadth is varied in such ratio that the area of any section cut from the wheel by the surface of the circular cylinders, whose axes coincide with that of the

shaft, shall be equal to such other sections at any distance from the centre; and these areas are so arranged in order

FIG. 45.

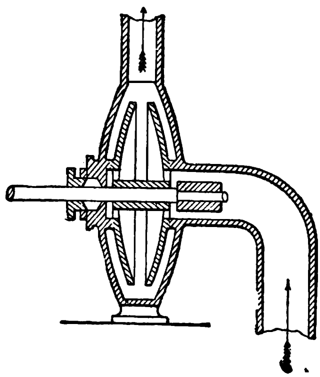
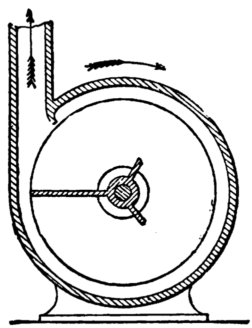


FIG. 46.



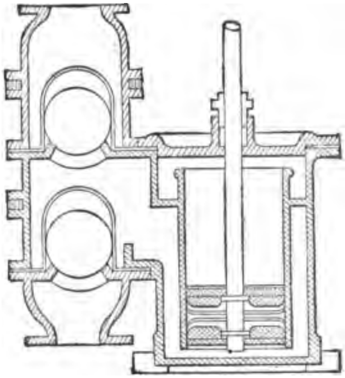
that the column of water or other fluid entering the wheel when in a state of revolution, may have an uninterrupted flow from the centre to the circumference, and that the quantity received and discharged may be constantly equal. The inner surfaces of the disc, or the annular opening around the whole circumference, has an area equal to the openings at which the water is admitted into the centre of the revolving wheel. In one of the cylinder covers or ends there is a bearing supporting the spindle on which the wheel is fixed, in the other cylinder cover there is a gland and stuffing-box, through which the shaft for the revolving wheel passes.

The "Castraise" pump, patented in England by Jean André Cecile Nestor Delpech, July 1854, is illustrated in Fig. 47.

These are sucking and forcing double-acting piston-

pumps, with a single pump-chamber. The piston is fitted with cup-leathers; the pump-chamber, which is either vertical or horizontal, is enclosed in a tank divided by a diaphragm perpendicular to the axis of the piston. The valves, four in number, are hollow indiarubber balls, weighted in the centre with small shot. They are arranged in pairs in two lateral boxes, a section of which is shown in Fig. 45; the lower valve is the suction, and the upper the delivery valve. Each half of the water-box enclosing the pump-chamber is in constant communication with the interval between the two valves of a box.

Fig. 47.



In the illustration, the lower part of the tank corresponds with the valves represented. While the piston is sucking through one box, it is forcing through the other, which is the case with all double-acting pumps. The peculiarity of the "Castraise" pump is the use of the water-tank spoken of above, the effect of which is to render the volume of water contained in the pump much larger than

the volume of the pump-barrel; the consequence of this is that a portion of the water acted on by suction traverses the valve-chamber only, without passing through the pump-chamber, the piston being, so to speak, always in contact with the same water. This arrangement enables

FIG. 48.

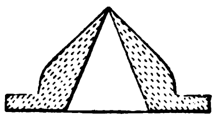


FIG. 49.

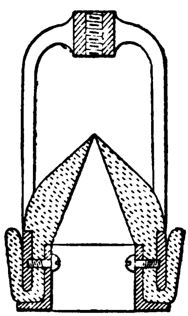
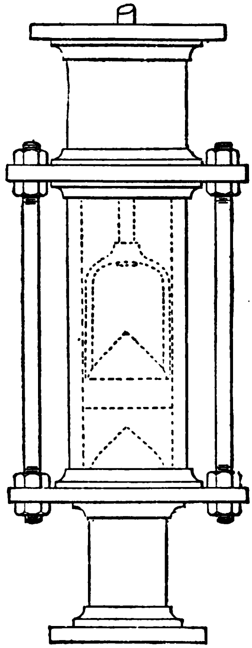


FIG. 50.



the pump to work in muddy water, by placing the piston beyond the reach of injury from the passage of gravel, grit, &c.

Mr. Louis Guillaume Perreaux, in the year 1856, patented a very useful single-acting bucket-pump, the

description of which the Author has taken from "Spon's Dictionary of Engineering," page 1945. "The essential character of Perreaux's pump consists in the use of indiarubber valves" (illustrated in Fig. 48), "cylindrical at the base and flat at the top, which gives them the form of the mouth-piece of a clarionet. Like this latter, they terminate in two lips, which, under the influence of the pressure resulting from the rising and falling of the piston, open and close through the elasticity of the material. One advantage of this elasticity is that the solid matter brought in with the water may pass through without causing injury. The retaining valve is placed at the bottom of the cylinder, whilst the other, suitably extended in a cylindrical form at its base, forms a piston." (Illustrated in Fig. 49.) "The indiarubber is stiffened with ribs of the same material. The pump-chamber is of copper" (illustrated in Fig. 50), "and may be enclosed in wood. The upper part, which is closed, serves as an air-reservoir, if the pump is simply a suction-pump; if it is to be forcing as well, a small copper cylinder placed at the side, and also provided with an indiarubber valve, forms the air-reservoir. The various parts are easily taken to pieces. These very simple constructions may be made of any form; they are of great service for agricultural purposes, and whenever it is required to raise water loaded with sand."

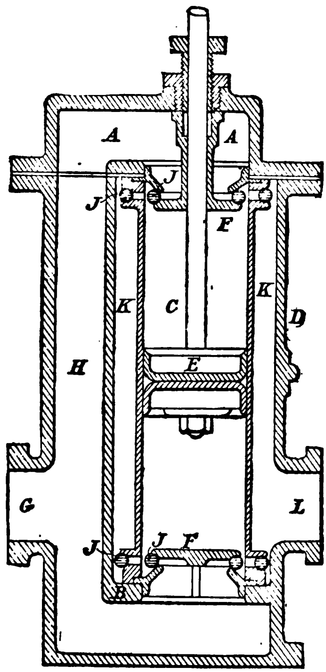
The late Mr. Charles Randolf, of Glasgow, read a paper before the Institute of Mechanical Engineers, 1856, in which he gave a description of an air-compressing pump, made by Messrs. Randolf and Elder, now John Elder and Co., for Govan Colliery. The pumps were vertical, 21 inches in diameter by 18 inches stroke. The pumps were single-acting of the bucket type. The valves were brass balls, of which there were three sets to each

pump, each set consisting of 44 balls, 2 inches diameter, arranged in three concentric rings (21 in the outside circle, 15 in the middle circle, and 8 in the inside circle), the balls were confined by separate cages to a lift of ½ inch. In consequence of the high pressure of the air, amounting to 30 lbs. per square inch, provisions were made for preventing leakage through the valves, by a stratum of water constantly covering the piston's valves and the delivery and inlet valves. A small pump, 3 inches diameter and 10 inches stroke, was employed to supply water for this purpose, and delivered it into a centre reservoir.

Figs. 51 and 52 are illustrations of a double-acting piston-pump of a peculiar construction, invented and patented by Mr. Stephen Holman, in the year 1857. Fig. 51 is a sectional elevation; Fig. 52 a sectional plan of a vertical arrangement of this pump:—This invention relates, *firstly*, to a novel arrangement of pump. The pump consists of a barrel or inner cylinder C, placed within a cylindrical casing D, (which may be used as an air-vessel), leaving a space all round between the inner and outer cylinder to permit the discharge of the fluid at or beyond each end of the barrel alternately. The piston E, in its reciprocating motion to and fro in the barrel, operates upon the suction and delivery valves so as to cause the water or other fluid to flow into and out of the pump, whichever way it is moved; it will thus be a double-acting pump. The delivery valves J J are made to encircle the outside of the cylinder or working-barrel, or seatings at the top and bottom; the upper suction valve F, or compound valves (as the case may be), to encircle the rod and to be operated upon from the bottom side of the piston. The pump cover A is constructed with a chamber or space formed all round the stuffing-box, so

that at the descent of the piston the fluid will be admitted to the barrel above the piston through the upper suction

Fig. 51.



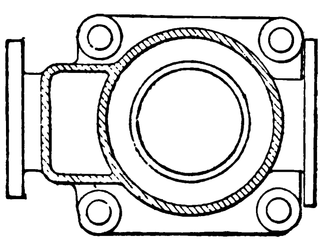


Fig. 52.

valve or valves, and at the same time forced out from the barrel by the lower side of the piston through the lower delivery-valve; and at the ascent of the piston the fluid will be admitted to the barrel below the piston through the lower suction-valve, and at the same time be forced out from the barrel by the top side of the piston through the upper delivery-valve. The bottom of the pump B, has also a hollow space or chamber for the water or other fluid to pass freely to the lower suction-valve. The fluid may be conducted to the top and bottom of the pump by separate suction pipes, or by a suction pipe common to both, and may be discharged from the pump through one or more outlets in the outer cylinder or case. For many purposes no other support will be necessary for the working-barrel than that of holding it between the pump cover A and bottom B; the cover and bottom being secured by bolts, or any other convenient mode of fastening to the case or outer cylinder, are at the same operation made to press on each end of the working-barrel, which may have flexible rings between to ensure soundness of joint, thus leaving the outside of the working-barrel entirely free.

A patent was granted to Daniel Evans and George Jones, in 1858, for "Improvements in Pumps." The improvements are illustrated in Figs. 53 and 54, in which the ordinary clack-valves are used, and Figs. 55 and 56, where the slide-valve is substituted for the clack-valves. A is the pump-barrel; B B pump pistons; C internal piston-rod; D hollow or external piston-rod; E, suction-pipe; F, delivery-pipe; G, air-vessel; H, suction-valve; J, delivery-valve; K, slide-valve. It will be seen from the illustrations that the pump-barrel A has three ports or openings, one L near each end, and one M in the middle of its length; within this barrel or cylinder two solid pistons B B are used, which are fixed to the end of their

respective piston-rods, one of which piston-rods D is hollow to admit of another piston-rod C sliding or working

Fig. 54.

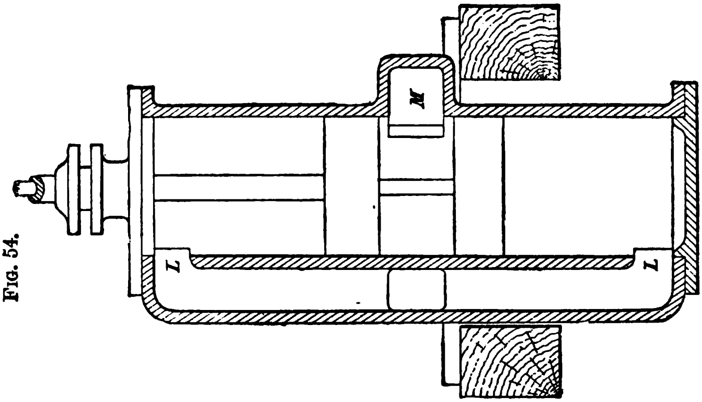
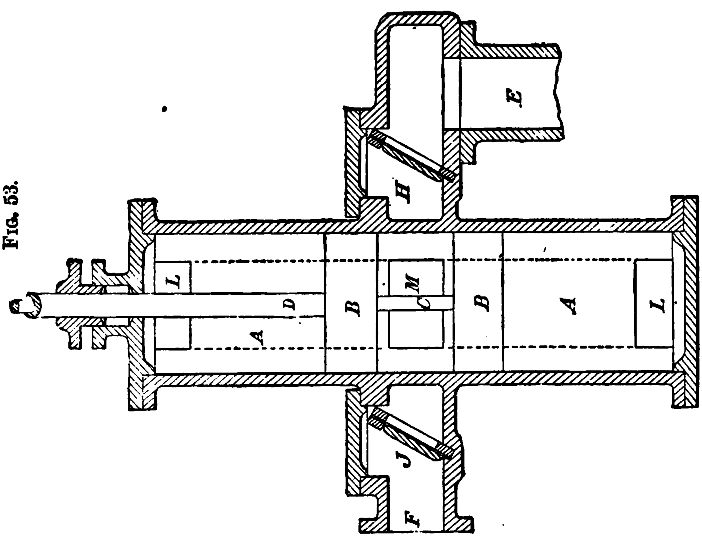


Fig. 53.



through; these piston-rods are worked by cranks or other suitable means, so that the pistons alternately come towards and recede from each other; when they are coming towards each other, the fluid between them is driven out

FIG. 55.

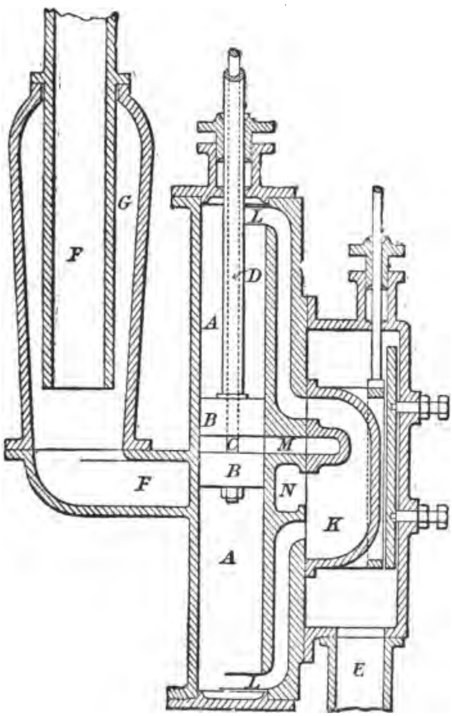
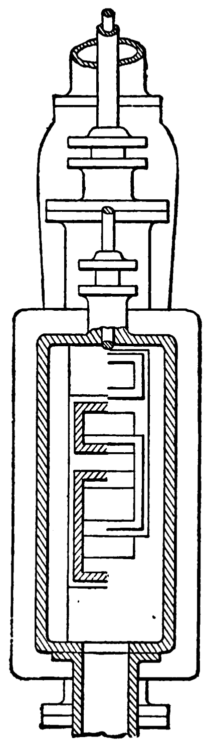


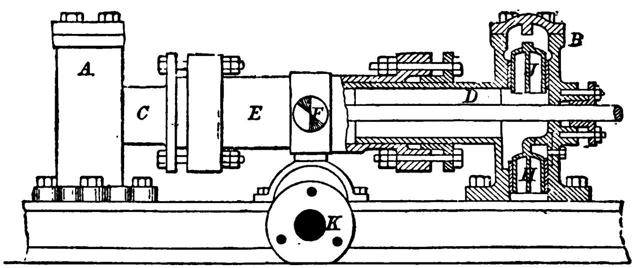
FIG. 56.



at the middle port M; when they are receding from each other the fluid is driven through the two end ports L L, the middle port M and the end ports L L acting as induc-

tion and eduction ways. On the exterior of the cylinder or barrel is a valve-box within which a slide-valve K is used, capable of opening a way between the end ports L L and the main eduction port N of the pump, when the middle port is acting as an induction port, and also capable of opening a port between the main outlet port of the pump and the middle port, when the two end ports L L are acting as induction ports. The fluid is received into the valve-box, from whence it passes into the barrel or cylinder, and is thence forced into the main outlet

FIG. 57.



port of the pump, as above explained. When constructing a pump with two barrels or cylinders, with pistons as above described, it is preferred to use only one valve-box and one slide-valve for the two cylinders, though each cylinder may have its valve and valve-box if desired.

Mr. Thomas Dunn, of Manchester, secured a patent in 1859 for a peculiar double-acting ram pump, one of which he exhibited in the London Exhibition, 1862. This pump has outwardly packed stuffing-boxes. The peculiar feature in the construction is that, instead of the ram or plunger moving backwards and forwards in the barrels at every stroke, the pump barrels are made to

slide backwards and forwards on the rams or plunger, the latter being stationary. This pump is illustrated in Fig. 57, which is half elevation and half sectional elevation. A, B, are the two valve-boxes firmly secured to the bed-plate by means of bolts and nuts; C, D, are the two plungers cast in one with the valve-boxes, and turned true and parallel; on these plungers or rams the working-barrel E is moved backwards and forwards by means of the crosshead pin F and a connecting-rod. H is the suction-valve, J the delivery-valve, and K the suction-pipe; the delivery pipe, not shown in the illustration, can be arranged at any convenient place above the delivery-valve J.

About the year 1860, Professor James Thompson secured a patent for a centrifugal pump, which he termed the "Whirlpool" pump, illustrated in Figs. 58 and 59.

The following is the inventor's own description:—"In centrifugal pumps doing actual work in raising water or forcing it against a pressure, the water necessarily has a considerable tangential velocity on leaving the circumference of the wheel. This velocity in wheels, where the vanes or blades are straight and radial, is the same as that of the circumference of the wheel; in others, in which the vanes are curved backwards, it is somewhat less; but in all cases it is so great that the water on leaving the wheel carries away, in its energy of motion, a large and important part of the work applied to the wheel by the steam-engine or other prime mover. This energy of motion in centrifugal wheels, as ordinarily constructed, is mainly consumed in friction and eddies in the discharge-pipe, which receives the water or air directly from the circumference of the wheel. In the improved centrifugal pump there is provided around the circumference of impeller, an exterior chamber, in which the water continues some time

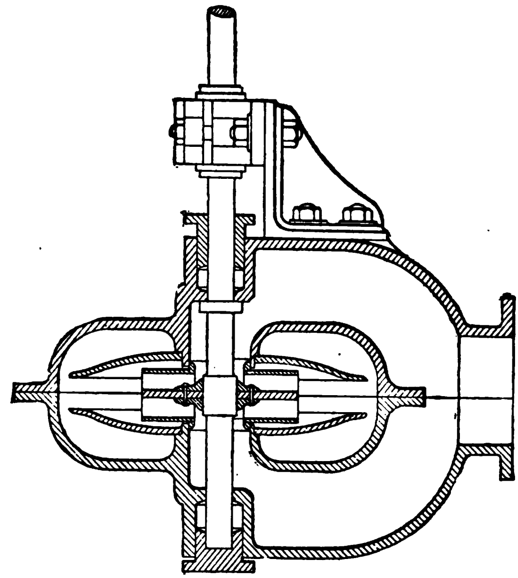


FIG. 59.

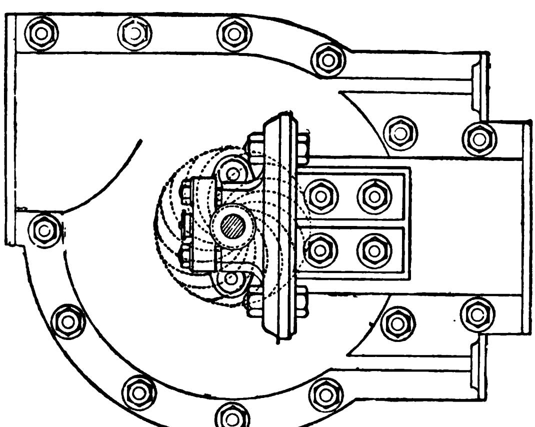


FIG. 58.

revolving, in consequence of the rotating motion it has on leaving the wheel. This chamber is called the exterior 'whirlpool' chamber, and is ordinarily about double the size of the impeller in diameter. The water revolving in this chamber is in the same condition as water revolving in the whirlpool, which I called the *'whirlpool' of equal energies*, or *free mobility*. In this whirlpool (when some slight modifying causes, such as the fluid friction, is neglected) the velocity of the water is inversely proportional to its distance from the centre, and the sum of the accumulated work or energy of motion and the work in the condition of water pressure of two equal masses of water in the same horizontal plane, is the same, so that when the velocity diminishes, the pressure increases, the energy of motion given up in the diminution of velocity being converted into water pressure. It is by this convertion of energy in motion into water pressure, through the medium of the exterior 'whirlpool,' that a decided increase in working efficiency of the centrifugal pump is attained; the work contained in the rapid motion of the water leaving the wheel—which in centrifugal pumps, as ordinarily constructed, is wasted—being in the improved pump usefully employed in increasing the pumping power of the machine."

The impeller is constructed with a middle plate, having a boss in the centre for fixing upon the shaft, and two outer discs or covers, with circular orifices for admitting the water. Between the middle plate and the covers are fixed curved vanes, extending from the central orifice to the outer circumference of the wheel.

There is also an outlet chamber arranged to receive the water from all parts of the circumference of the "Whirlpool"; this outlet chamber is separated from the whirlpool bv conical discs, which prevent any slowly-moving or

eddying water from breaking into and disturbing the whirlpool.

The vanes and covers of the impeller are made of rolled brass for the smaller sizes, and of sheet iron for the larger sizes, the centre or boss plate being of wrought iron in both cases. The advantages of the thin vanes for avoiding obstruction to the entering water, and of a large number of vanes for preserving the proper direction of the water and preventing it becoming broken and agitated in its passage through the impeller, are obvious.

A V-shaped pump was patented by Mr. J. L. Norton, about the year 1860. A paper was read on this pump, before the Institute of Mechanical Engineers, January 28th, 1864, by Mr. John J. Bircket, of Liverpool, from which the author has taken the following description and illustrations (Figs. 60 and 61). Fig. 60 is a sectional elevation and Fig. 61 a cross section.

"The lower half, A, of the barrel acts as a stationary bed, being fixed water-tight to the foundation-plate B; the working portions are planed true through their entire length, and the angle of the V is 90 degrees, as seen in the transverse section Fig. 61. The upper or sliding half, C, of the barrel is also planed true throughout its length inside, as well as upon its return flanges, which make a water-tight joint with the lower half A. The barrel is made complete by the two end covers D D, in each of which is an aperture closed by a leather flap-valve E; these covers are bolted on the sliding barrel C, and are fitted true by planed faces upon the V bed A, with which they make a water-tight joint. A handle F, is fixed to the sliding barrel C, for convenience of lifting it out of its seat. The stationary bucket G, is fixed to the bed A, and makes a water-tight joint both with the bed A and with the sliding barrel C; it communicates by means of

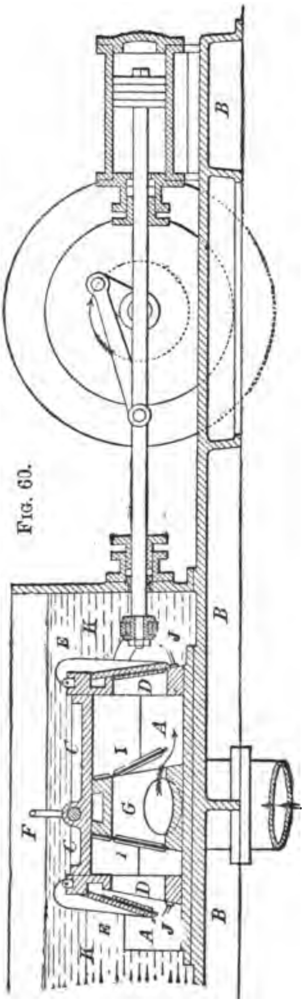


Fig. 60.

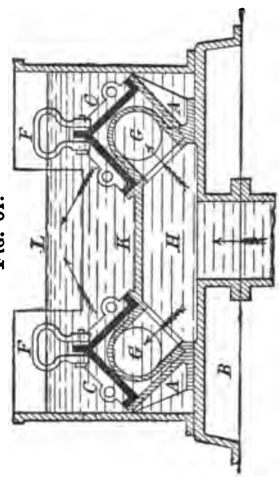


Fig. 61.

the central opening with the suction chamber H, and opens at both ends into the pump-barrel, each opening being provided with a leather flap-valve I. The bucket is thus made to answer as the suction valve-box, whereby the pump is rendered double-acting by means of only a single valve-box.

"When the sliding barrel C is set in motion, the water is drawn into it at one end through one of the suction valves I; while at the same time the water contained in the other end of the barrel is discharged through the delivery valve E, at that end. The delivery valves E, are prevented from opening too far by the catches J, and a similar provision is made by the two suction valves I, which are connected together by a chain. The pump works in a cistern K, upon the foundation-plate B, into which it delivers the water raised; and a continuous discharge takes place through the overflow spout L, which is placed as such a height as to keep all joints of the pump constantly immersed in the water, thus making them air-tight. When it is desired to use the pump as a force-pump, it is only necessary to close the top of the cistern, and provide a rising main from the cistern to the height at which the water is to be delivered."

A centrifugal pump with horizontal spindle, and vanes on one side of the impeller only, was introduced by Mr. Andrews about this time (1860), and is illustrated in Figs. 62, 63, and 64.

Fig. 62 is a sectional elevation; Fig. 63 the rotating disc or impeller, and propelling wings; and Fig. 64 the stationary boss and spiral flanges. A is the base of the pump, cast in one piece with the case C, and strengthened by brackets. To the chamber C is attached, by flanges *b*, *b'*, the conducting case, composed of two parts *D*, *D'*, united by flanges *d*, *d'*, and forming a spiral discharge

FIG. 62.

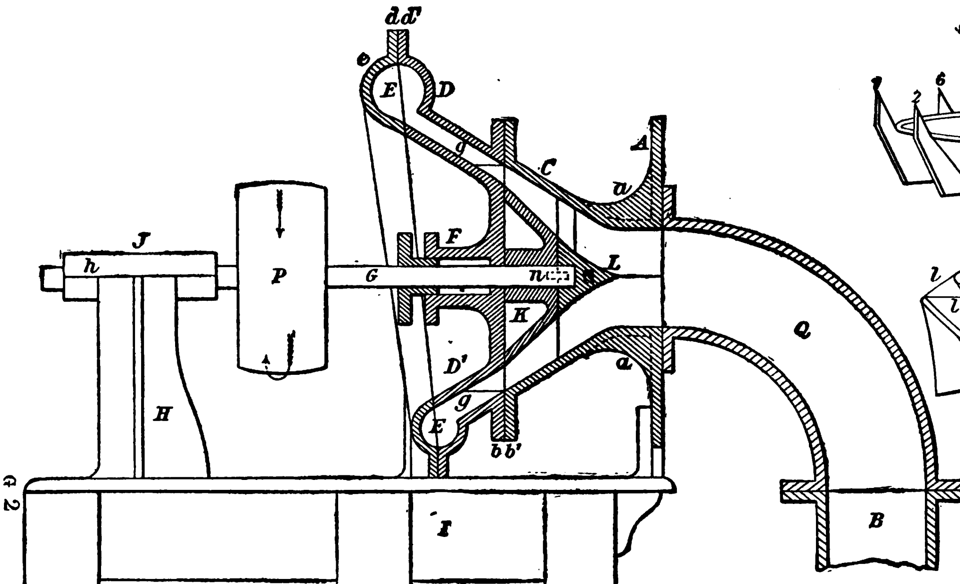
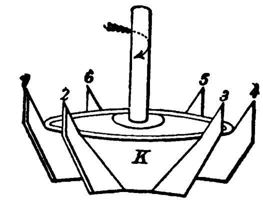


FIG. 63.



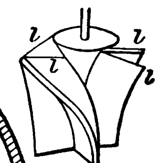


FIG. 64.

passage *g* and E, commencing at C, and gradually enlarging to the outlet *e*. F is the stuffing-box, through which passes the cast-steel driving shaft G, having a series of grooves turned in its surface at J, which are accurately fitted in a Babbitt's metal box in the standard H, its cap *h* counteracting all tendency to end thrust or vibration. I is the bedplate with standard H cast upon it, and brackets, to which the pump is secured by the flanges *d d′*, and base A. When required to be run vertically no bed plate is used, but the pump is secured by the base A. The base A also forms a flange, to which is bolted the bend Q, with which the suction-pipe B is attached (shown broken off in the illustration); this pipe has a foot-valve at its lower end. K is the disc, secured upon shaft C, having wings, 1, 2, 3, 4, 5, and 6 upon its periphery, closely fitting the space between which they revolve without touching. Their discharge ends extend beyond K, close to the case D′, without touching it, and terminate on a line parallel to the shaft G. L is the boss connected by flanges *l l l l*, to the chamber C, forming spiral inductive passages. In the end of shaft G is a steel button *n*, with a convex face, which revolves in contact with the convex end of the step N, secured in the boss L, supporting the shaft and and disc; when run vertically, motion is communicated to the disc by a belt upon the pulley P.

The pump and pipes first being filled with water, rapid motion is given to the impeller K, when the centrifugal force imparted to the water between the wings causes it to flow through the passages *g* and E, to the outlet *e*; a vacuum being thereby created between the wings, which causes the water to rise through the pipe B, to keep up the supply.

By means of the spiral passages around the boss L, the water from the suction-pipe is turned gradually from a

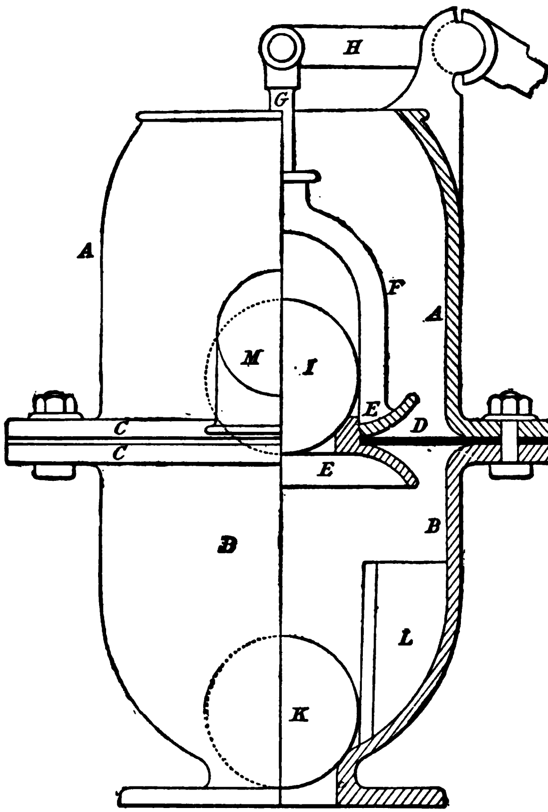
direct forward course, and delivered to the propelling wings in the line of their action; thence through the spiral passages *g* and E it is again, by an easy gradual curve, brought back to a straight course upon reaching *e*. The wings on the impeller K, passing beyond its outer edge, create and maintain a vacuum between it and the case D, and prevent sand, dirt, &c., from coming into contact with the shaft.

The diaphragm pump, illustrated in Fig. 65, was invented and patented by Mr. J. L. Norton in the year 1861. On the upper end of a pipe leading to the source of supply is a chamber of convenient form, and the opening of the supply pipe into the chamber is fitted with a ball valve. The top of the chamber is closed with a flexible disc, usually of leather, with a hole through it at the centre. In this hole a metal ring is fixed, to which also a ball valve is fitted, opening out of the chamber already mentioned. To the metal ring in the disc a rod is attached, by which the centre of the disc may be moved up and down, deflecting the disc alternately in either direction, when the chamber is increased and a partial vacuum formed in it; this is at once supplied by liquid entering the chamber by the supply pipe. When the disc is deflected downwards the capacity of the chamber is diminished, and, as the valve prevents the liquid returning into the supply pipe, it is forced to pass through the passage in the disc, raising the valve; it thus enters another chamber which is connected with a pipe for conducting the liquid to the locality where it is required. The apparatus may be made double-acting, by dispensing with the passages through the disc, and adapting supply and exit pipes with suitable valves to each chamber.

Fig. 65 is an elevation, and half-section of this pump.

A is the upper, and B the lower shell or box, having each a flange C C, between which flanges the outer diameter of

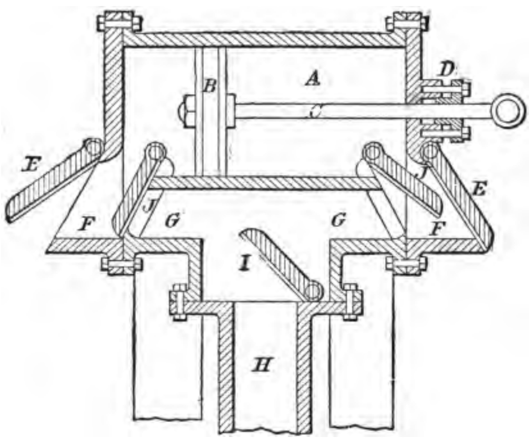
FIG. 65.



the diaphragm D is held. The diaphragm is made of leather or other suitable flexible material, made or blocked

out by moulds to a suitable shape, and has a hole in the centre, to which is fixed a valve seat and guards E E, above and below, to support the diaphragm. The lower guard is formed in one piece with the valve seat; the upper guard screws on to the piece in which the valve seat is formed, and the diaphragm is nipped between the two guards; to the upper guard is fixed a bridge-piece F, by which the diaphragm is connected with the rod G and pump-handle H. The valves are made of iron covered

Fig. 66.



with indiarubber; the upper valve is marked I, and the lower K. The bridge-piece F forms a guard to keep the upper valve I in its place, and allow it to rise and fall, and the guards L, one of which only is shown, keeps the lower valve in its place; M is the delivery spout.

The next patent we will refer to was secured by Mr. R. A. Godwin, in August 1861. This pump is illustrated in Fig. 66, which is a vertical section constructed according

to the invention. A is the working-barrel or pump cylinder, which is fixed in a horizontal position in a suitable frame; B is the piston; C the piston-rod, which works through a stuffing-box D at one end of the barrel or pump cylinder. The openings through which the water passes into and from pump-barrel are made at the lower side of and at the ends of barrel, as shown; E E are the outlet or delivery valves, which are hung, by preference, at their upper sides, and rest, when shut, on inclined seats formed at the outlets or openings F F, of the barrel, and such valves E E open outwards; G G are two branch suction-pipes, which are connected to the descending suction-pipe H, which has a retaining valve I, as shown; J J are the two inlet valves in the branch suction-pipe G; these valves are hung, by preference, at their upper part, and they shut down on inclined seats, parallel, or nearly so, with the seats of the outlet valves E E.

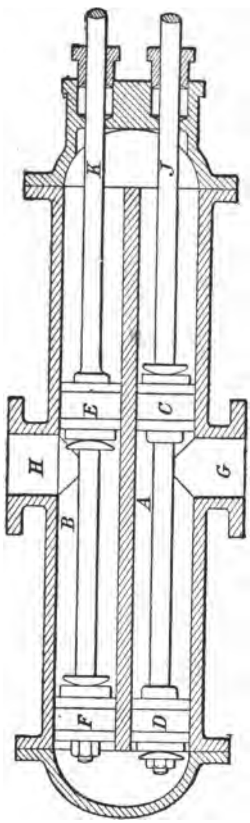


FIG. 67.

In 1862 we find another continuous flow pump, invented by Mr. Cowan, consisting of two working-barrels, one for

suction and one for delivery. This pump is illustrated in Fig. 67, being a sectional plan. A is the suction barrel, B the delivery barrel; each of the two barrels are fitted with two buckets, of which C and D are the suction

FIG. 9.

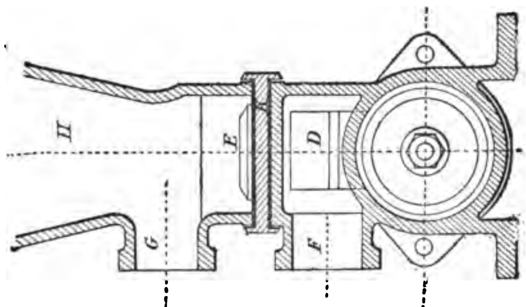
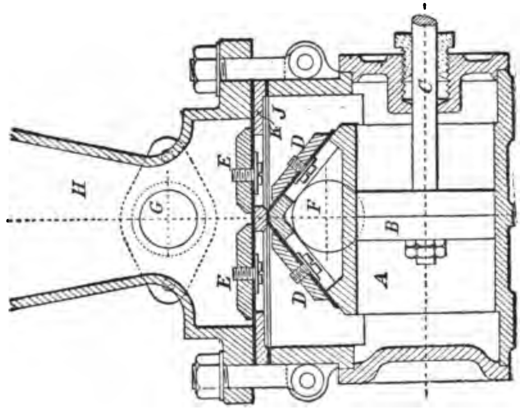


FIG. 68.



buckets, and E and F the delivery buckets. G is the suction branch and H the delivery branch; J is the pump rod for the suction buckets, and K the rod for the delivery

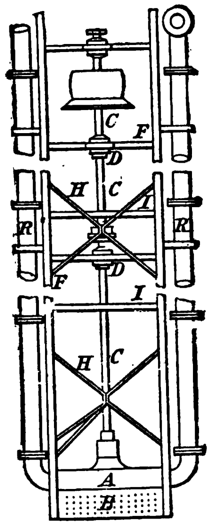
buckets. The buckets are all, in this case, fitted with indiarubber disc valves.

The "California" pump, invented by Mr. T. Hansbrow and introduced into England in 1862, is a very neat and convenient arrangement for small double-acting piston pumps for low lifts. It is illustrated in Figs. 68 and 69, and consists of a working-barrel A, piston B, piston-rod C; D D are the suction-valves, E E the delivery valves; F is the suction-pipe; G the delivery-pipe; H the air-vessel. It will be seen that the suction valves are arranged above the pump-barrel, so that the pump is always charged with water. The suction valves D D are cut out of one piece of leather, which also forms the joint between the pump body J and the delivery valve seat K; and the delivery valves E E are again cut out of one piece of leather, also forming the joint between the delivery valve seat K and the air-vessel H. The pump body J, delivery seat K, and the air-vessel H, are all joined by four hinged bolts, making the access to the valves very easy.

"There are but few large foundation works carried out in the course of which it does not become necessary to employ a greater or less amount of pumping power," says *Engineering*, of March 8th, 1867, page 225; "and in the large majority of instances the water which has to be raised carries with it, in a state of suspension, some proportion of solid matter. In many cases, the solid matter thus suspended is very considerable in quantity, and under such circumstances it becomes necessary that the pumping arrangements employed should be specially adapted to the work to be performed, and should be capable of standing rough usage. It is for work of this class that the pump, of which we give engravings" (Figs. 70, 71, 72, 73, and 74), "has been specially designed, the object of the inventor and patentee (patented in the year

1862), Mr. John Hyman Woodford, having been rather to produce a pump for the economical raising and delivery of pure water, than to provide engineers, contractors, builders, and others engaged in carrying out public works, with a pump which should be efficient under all the disadvantageous circumstances arising in practice.

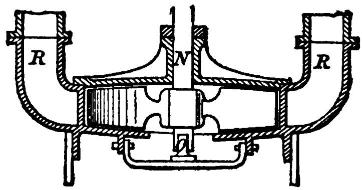
Fig. 70.



"In our engraving, Fig. 70 shows the elevation of one of these pumps, with the framing, shafting, and delivery pipes, as arranged for contractors' purposes. The pump A is affixed to a perforated wrought iron box B, which is immersed in the water to be pumped. The vertical driving shaft, C C C, is coupled by means of couplings D D, and supported partially on the wooden bearings E. The frame is made of angle-iron in 9 feet lengths F F,

fished together, and connected by diagonal braces H H, and ties I I. All the corresponding parts of the frame are made mutually interchangeable, and the holes are so arranged that the diagonal and cross-pieces may be placed higher or lower, if desired. The delivery pipes are screwed to the frame by the strips. The couplings D are slightly rounded on the face, allowing the shafting to

FIG. 71.



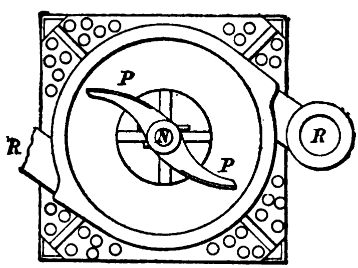


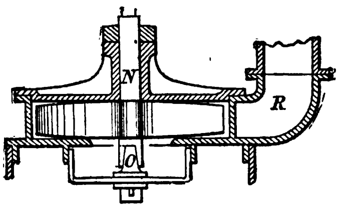
FIG. 72.

work freely, even when a little out of line. At the upper part, Fig. 70, is shown the driving pulley, this pulley being secured to any part of the shaft by means of a grooved key or set screw.

"In Figs. 71 and 72 are given enlarged views of a pump capable of raising 2000 gallons per minute, the diameter across the revolving arms or flyers being 2 feet 6 inches, and the speed being, as in all Mr. Woodford's pumps,

regulated according to the height to which the water has to be raised. A number of careful and frequently repeated experiments made with this pump have shown that a velocity of 500 feet per minute given to the extremities of the flyers, just ensures a full delivery on a lift of 1 foot, and for other lifts this velocity is increased in proportion to the square-root of the height. In putting down these

FIG. 73.



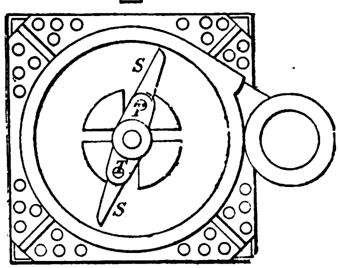


FIG. 74.

pumps, therefore, the rule now is to drive them at such a number of revolutions per minute, that the speed of the extremities of the arms in feet per minute is equal to the square-root of the height of the lift in feet multiplied by 500.

"Referring to Figs. 71 and 72, it will be seen that the pump has two revolving arms, P, only, these being of a curved form, and being made of wrought iron. The shaft

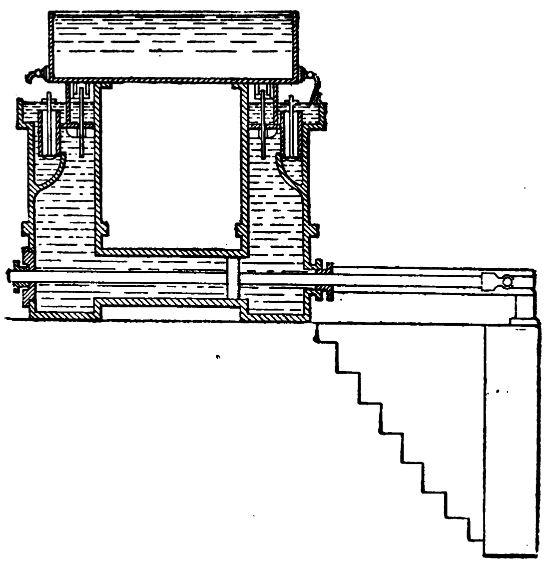
N, on which they are fixed, rests at its lower end on a steeled footstep O, this footstep projecting into a hollow formed in the lower end of the shaft, so that the bearing surfaces are protected from the action of sand, &c. The water delivered by the pump passes through the two branches, these leaving the case tangentially, and communicating with a pair of wrought-iron uptakes or delivery pipes R, each 6 inches diameter.

"The pump above described, although giving very good results when employed in pumping water containing sand and gravel in suspension, is yet not preferred by Mr. Woodford for such a service. For passing large quantities of sand, gravel, stones, &c., in connection with water, the form of pump represented in Figs. 73 and 74 has been specially designed. In this pump the general arrangement is the same as in that shown in Figs. 71 and 72, but the flyers, S S, are made straight, and are each hinged as shown at T T. Should the flyers become stopped by fouling, they can be released by turning the shaft backwards; thus causing the arms to be moved inwards, by moving on the hinge T with which they are provided. It will be seen by the Figs. 73 and 74, that in this form of the pump one delivery-pipe only is employed, the reason for this being that, in order to carry up stones, &c., clearly, it is necessary to maintain a considerable upward velocity of water in the delivery pipe, and that, under the circumstances, a single pipe gives a much clearer passage for the stones, &c., than would be given by a pair of pipes of smaller diameter, having in combination the same sectional area as the single pipe."

In 1863, Messrs. Stewart and Kershaw gave another impulse to the subject of air compressing pumps, by patenting a system of pumping air, which they call the Italian system, and which consists of a horizontal cylinder,

filled with water, attached to two upright air-vessels, one at each end, as shown in Fig. 75. The piston moves in the middle of the water, driving it before, and drawing it behind, at each stroke, so that the water only comes in contact with the air. This is a most ingenious contrivance, as by it all the air is discharged from the cylinder, and when combined with stage pumping, which is here again patented, ought to be serviceable. The water helps to keep the air cool, and is disposed of by being sent

FIG. 75.



forward over the discharge valves, in portions at each stroke, and finally discharged from the receiver by a common trap-valve.

We find in the year 1864, a centrifugal pump, invented

by Messrs. Coignard & Co., of Paris, used at the Irrigation Works on the banks of the Nile. It differs from Appold's pump, inasmuch that it consists of two impellers A A, which the inventor calls screws, these are placed symmetrically upon the spindle D. The water enters the casing through the suction-inlet L, which is placed in the centre of the same; through the centre of the screws O, into the wheel I, passing through the orifices F F into the impellers, which impart to it an increased velocity up to the circumference at G G G G: thence it flows through the passages M M M M, into the delivery pipe N. The form of the impellers is such that the section of the passages decreases from the centre to the circumference, and increases from the issue M up to the delivery pipe N, to vary inversely with the velocity. Small holes R R admit the accumulated air in the top of the casing to pass up into the delivery pipe. The centre spindle passes through the stuffing-boxes and glands P, the pressure of which can be regulated at pleasure. The whole is mounted on a strong bed-plate S. This pump is shown in Figs. 76 and 77.

Drawbaugh's rotary pump, is one of a host of pumps which differ very little from one another This was secured by letters patent in the year 1866.

Fig. 78 is a perspective view, with cover or head removed, showing the interior mechanical arrangement; Fig. 79 is a perspective view of the cover or head of the pump, showing the position and comparative size of the recesses, a similar recess being upon the corresponding opposite interior side.

A is a pump-case, through which the liquid is to be lifted and forced. Within the said pump-case are two hubs, each having flanges or pistons of a peculiar shape. These hubs are denoted by the letters B and C. The pistons on the former are denoted by the letters D and E,

and on the latter by T T, having recesses R R between the pistons.

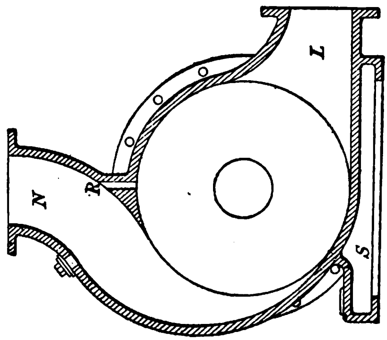


Fig. 77.

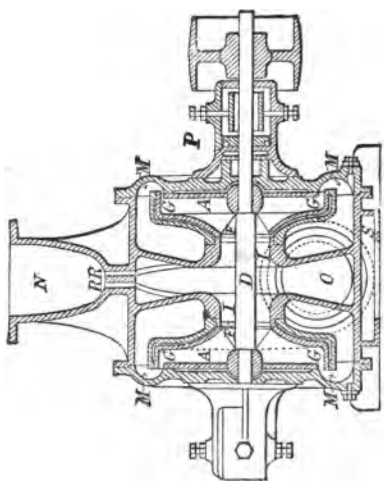


Fig. 76.

The hub B is moved by the application of power to the driving shaft, which is seen broken off at F.

The pistons or flanges D and E, on the hub B, are so

constructed and arranged that when describing their outer semi-revolutions, the external surface of each

FIG. 78.

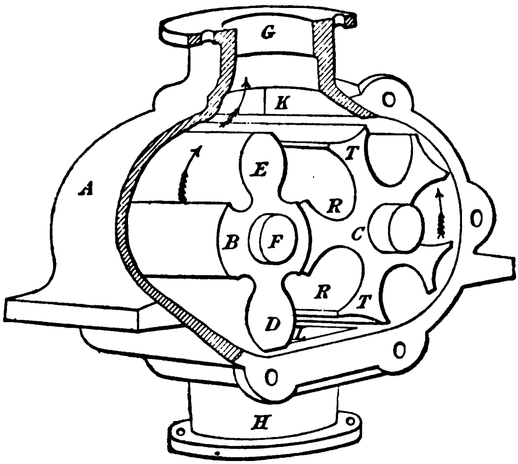
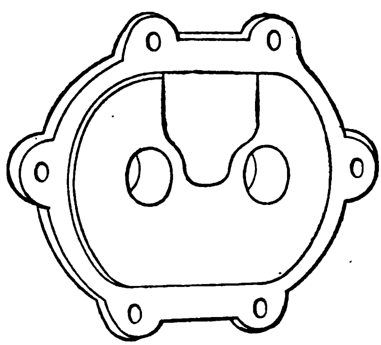


FIG. 79.



respectively moves in close contiguity with the interior semi-circular surface cf that portion of the interior case

of the pump, and in making their inner semi-revolution they work in contact from point to point through their entire extent with the surfaces of the concave recesses R R, the whole being so constructed and arranged that the convex surface of the one shall impinge upon and press directly against the concave surface of the other, from point to point, in regular continuity, so as to pass out from between the two surfaces all the liquid, and cause it to flow toward the eduction or delivery pipe G, of the pump.

In like manner the pistons T T, on the hub C, throughout their entire semi-revolutions, move in close contiguity with the interior semi-circular surface of the external case of the pump, so that the liquid cannot flow backward past these pistons, toward the induction or suction-pipe H.

In this manner all the liquid which is pressed into the recesses R R, and the small concavities at the outer extremities of the piston T T of the hub C, as well as all the liquid which is cut-off at each semi-revolution of the hub B, by the flanges or pistons D and E respectively, is carried forward towards the discharge pipe G, and cannot return towards the suction-pipe H.

In order that the machinery should work without strain, there is provided a recess K, on the interior side of the cover or head, and a like recess on the opposite interior flat surface of the pump-case which is swept by these hubs and pistons. Both these recesses open upward towards the delivery pipe G, so that the piston E, when passing into the corresponding recess R, may force the liquid in such recess R, into the recess K, of the cover or head, and a corresponding recess K, on the opposite interior flat surface of the pump-case, and thus relieve the machine from all strain resulting from the

compression of the liquid, and enable it to flow readily and freely from the recesses R R, as the pistons D and E enter them. As a further relief from strain, this pump is provided with two square chambers L L, of a corresponding length with the hub and pistons, thus allowing the liquid to enter and discharge freely.

From the construction of the hubs B and C, and their pistons, it will be seen that the motion of the hub C is not constant, but intermittent, being at rest from the time the neck of the piston D leaves the external edge of the piston T upon one side, until the neck of the piston E strikes the edge of the same piston T on the opposite side.

By giving the hub C an intermittent motion, the driving hub B is made with but two pistons, of such size and shape as to give greater strength, more space for water within the pump-case, and consequently a greater flow of water from the pump when in operation, than could be done if the hub had each the same number of similarly shaped pistons, and should be kept in constant motion, or move simultaneously with each other.

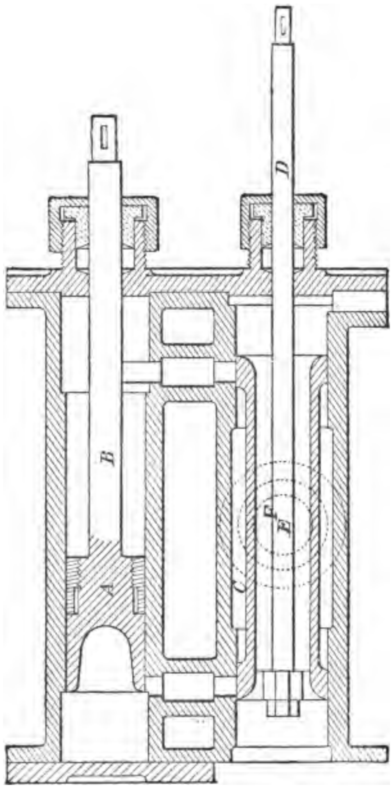
By this construction and motion of hubs and pistons, the objection against many, if not all, the rotary pumps in use, namely, the great amount of friction when working under pressure, is overcome, for when the pistons D and E of the propelling hub B are sustaining the resistance of the liquid, the pistons T T of the hub C opposite each other are equally acted upon by the liquid, leaving the hub C, with its pistons, in a state of equilibrium; consequently but a small amount of force is required to move the hub C, and but little friction or wear will result, even when working the pump under a heavy pressure.

A pump consisting of two pistons in one barrel, and a corresponding set of valves for twin double-acting piston-

pumps, was patented by Mr. Stephen Holman in the year 1867.

About this year (1867), Messrs. Laird Brothers, of

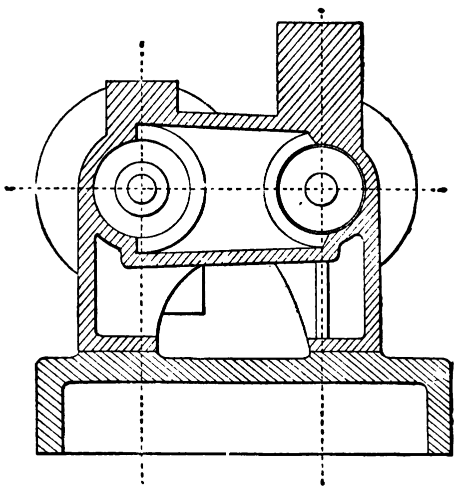
FIG. 80.



Birkenhead, introduced a double-acting piston-pump, fitted with a piston valve. This pump is shown in sectional elevation Fig. 80, and cross-section Fig. 81. A

is the pump-piston; B the pump-rod; C the piston-valve; D the valve-spindle, actuated by an eccentric; E is the suction inlet, shown in dotted lines; F the delivery branch. The delivery water from the right-hand end of the pump passes through the hollow of the piston-valve.

FIG. 81.



Messrs. J. and H. Gwynne secured a patent for an improved centrifugal pump in the year 1868. It is illustrated in Figs. 82, 83, 84, and 85.

Fig. 82 is an elevation; Fig. 83 a sectional end view; Fig. 84 a front view of the impeller; and Fig. 85 a cross section of the impeller.

The pump consists of an outer case E, with a disc or impeller A, having six arms or blades B cast on a centre boss. A centre plate C springs from the boss and gradually decreases in thickness to a knife-edge, bringing

the separate currents of water into each side of the disc, without producing any eddy or reflux. The arms are

FIG. 82.

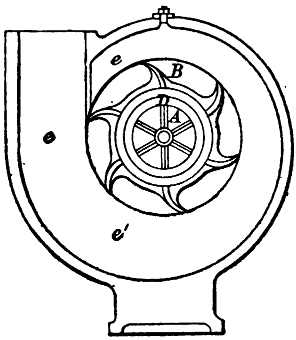
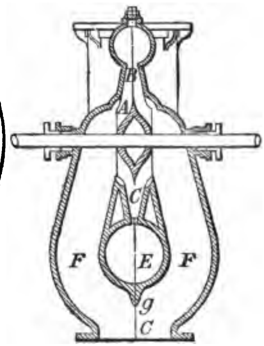
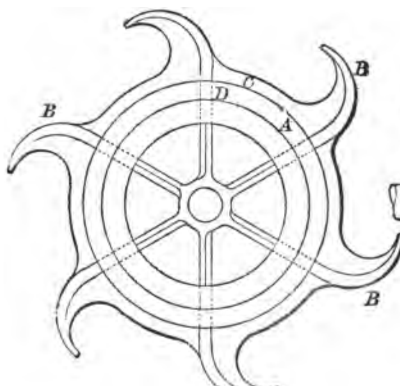


FIG. 83.





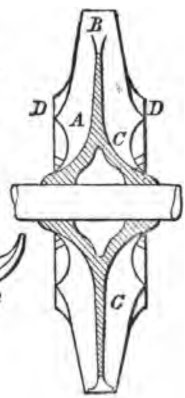


FIG. 84.

FIG. 85.

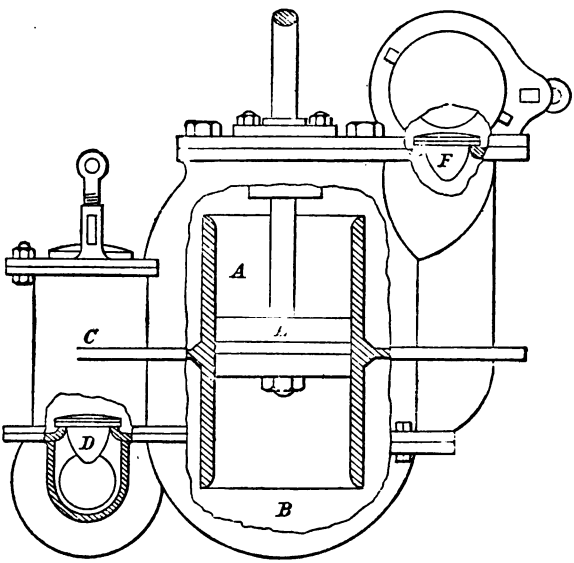
radial two-thirds of the length, and curved off towards the periphery in an opposite direction to the line of

rotation, in order to direct the water into the sweep of the case and prevent it rushing against the outer side of the discharge passages. Two rings D, Fig. 85, one on each side of the arms, form the bearing surface. The suction passages F F branch off from the suction pipe G at the point *g*. The bottom part of the casing E is thinned off to a knife-edge, in order to prevent any obstruction to the water. A space is left between the passages and the case, to carry the suction pipe F F over the enlargement of the discharge passage in a straight line to the opening in the centre of the disc A, at which point they curve into the top of the openings. The discharge passage is sprung from the periphery of the disc in the form of a helix or volute, commencing at the top of the case E and gradually increasing till it reaches the full size of the discharge pipe E′. That part of the pump casing E which contains the impeller is made of the same shape as the profile of the impeller, and similar in section, and of just sufficient size to permit the impeller to revolve, the bearings rings D being accurately fitted to the turned recess in the casing. By this means the usual side plates on the disc of centrifugal pumps are not required, the peculiar form of the pump casing acting in place of such plates, consequently the friction of the disc A is reduced. The whole of the disc and arms are steel, in one casting. The spindle passes through two stuffing-boxes cast on the casing E, to which are fitted gun-metal glands. A driving pulley is attached to the end of the spindle. Valves are placed at the bottom of the suction pipe to retain water when the pump is not at work.

A double-acting piston pump, very suitable for Colonial purposes—where skilled labour is scarce, consequently repairs are expensive and in some places almost impossible, except when they are of the simplest form, as

putting in fresh cup-leathers, which can be kept in stock, or putting new leather faces on the valves, which can be done by anybody who can cut a piece of leather—is illustrated in Fig. 86. This pump was invented and patented by Mr. M. W. A. Herring, of Chertsey, in the year 1869. The pump barrel A is open at both ends, and supplied at

FIG. 86.



its centre by a ring standing out from its exterior and passing to the sides of a casing B, by which the pump barrel is surrounded. The casing is thus divided into two compartments—one open to the top end of the cylinder, the other to the bottom end.

The casing has also cast with it the central portion of the inlet or suction valve-box C; this valve-box is divided

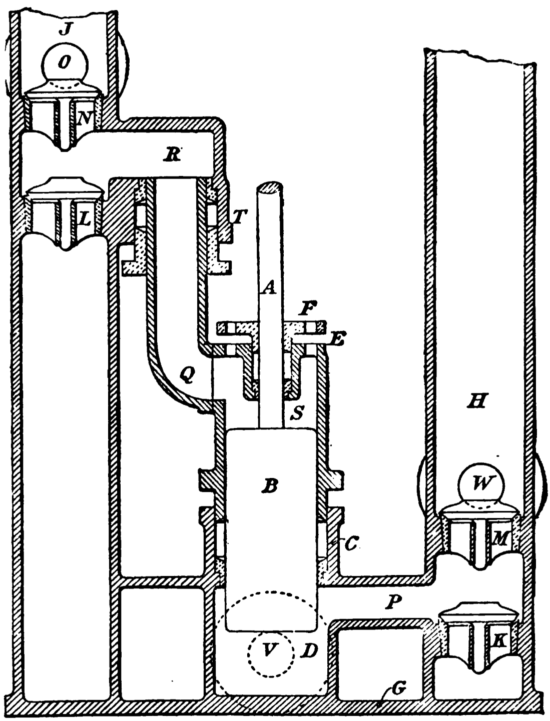
horizontally by a partition into two compartments. The upper compartment of the valve-box is divided into two by a vertical partition, and from the compartment on one side of the vertical partition a passage is made opening into the upper part of the casing, whilst from the compartment on the other side of the vertical partition there is a passage to the lower casing; from the lower compartment of the valve-box is led the suction-pipe, and the lower compartment, by two passages fitted with suction-valves, communicates with the two compartments above it. The manner in which the valve-box is constructed and fitted at its upper end with covers by which the suction-valve D can be got at for examination and repairs, is clearly shown in the illustration. On the opposite side of the pump the casing has similarly cast with it the outlet or delivery passages fitted with delivery valves F, and these valves are both covered over by one cap, from which are two outlet or delivery passages, to either one or other of which the delivery pipe may be attached, whilst the other is closed by a screw cap. The piston L of the pump is fitted with double-cupped leathers.

A vertical double-acting plunger pump, with one plunger only, of a rather peculiar construction, was patented in England in the year 1870, by Messrs. Richard Potter Pearn and Frank Kelsey Pearn.

Fig. 87 is a sectional elevation of a pump of this description; A is the piston-rod, to which is connected the plunger B; this plunger may be moved up and down or to and fro by any arrangement of motive power. The plunger B works through a stuffing-box C, which is placed in the upper end of the cylinder or working barrel D; the upper cylinder S forms the gland; this cylinder S is provided with a cover or top E, the stuffing-box, and gland F; the two cylinders D and S fit together, as shown in

the illustration, and are bolted together; the pump barrel D is in one casting with the foundation plate G and the columns H and J, the lower ends of which are provided

FIG. 87.



with seatings for the admission or suction valves K and L, and the discharge or delivery valves M and N, while the upper parts of the columns form air-vessels to keep up a constant flow in the delivery pipe O. The passage P

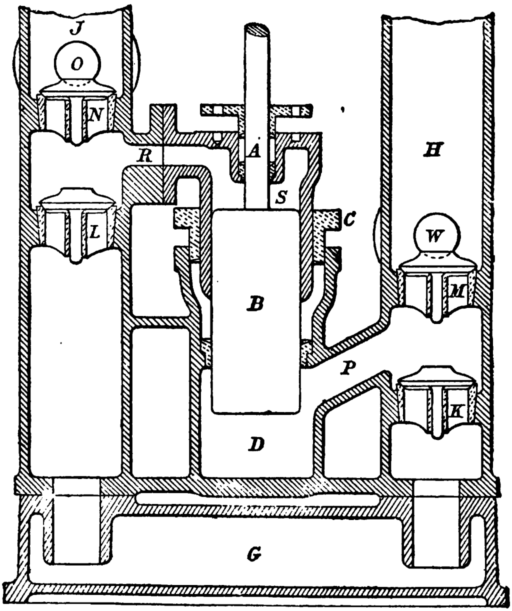
connects the pump barrel D with the right-hand column H, and the elbow pipe Q and passage R connect the upper portion S of the pump barrel to the left-hand column J. The pipe R passes through a stuffing-box T in the upper part of the column J.

The mode of operation is as follows:—When the plunger B is ascending; the fluid to the pump is now entering at the right-hand end of the supply pipe V, and after passing the valve K, it flows along the passage P, to fill the pump barrel D, and the plunger ascends; at the same time the fluid that was above the plunger B is being forced up the elbow Q into the passage R, and through the delivery valve N into the discharge pipe O. As soon as the plunger begins to descend, the pressure of the fluid closes the valves K and N that had been open, and opens the corresponding valves L and M that had been closed, thereby allowing the fluid to enter the supply valve L at the left-hand side, and to escape through the right-hand delivery valve M into the discharge pipe W. Owing to this peculiar construction, the pump gland and stuffing-box C can be repacked without removing any part of the machine; it is only necessary to unscrew the bolts by which the upper and lower portions of the pump barrel are united, the upper portion S can then be lifted up to give access to the packing.

A modification of this pump is illustrated in Fig. 88, which is a sectional elevation. The letters correspond with those in Fig. 87; the principal difference being that the top part of the barrel S is fixed, consequently the gland and stuffing-box T is dispensed with, and the two barrels D and S are packed by one gland and stuffing-box C, which is clearly shown in the illustration. The advantage is so clear that it is hardly necessary to comment upon it.

The helical pump, patented by Messrs. Bolton and Imray, is illustrated in *Engineering*, 1872. It consists merely of a revolving wheel or fan, having around its

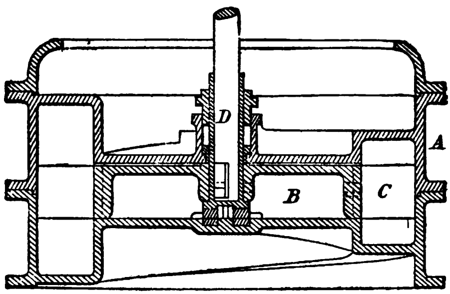
FIG. 88.



periphery a series of vanes or floats, as shown in Figs. 89 and 90. The wheel rotates in a casing furnished with tangental branches for suction at E and delivery at F, the former being placed at a lower level than the latter, and the form of the casing A being such that the water, as it rotates under the action of the fan B, is made to follow a helical course, and is thus, while travelling round the casing, lifted from the level of the suction E to that of the delivery orifice F.

It will be seen from what has been written that the helical pump in its mode of action differs from ordinary centrifugal pumps. In the latter, it is essential that the

FIG. 89.



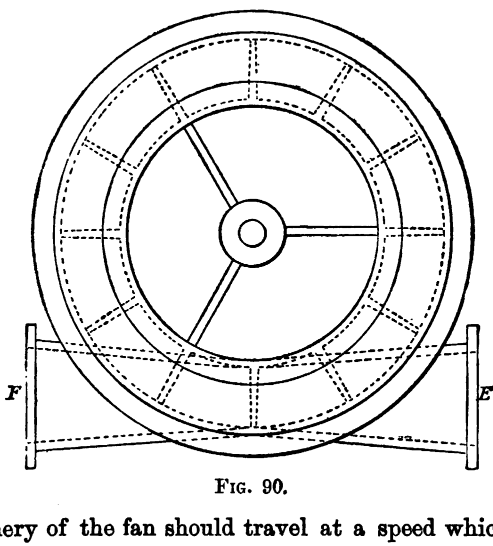


FIG. 90.

periphery of the fan should travel at a speed which is at least equal to that acquired by a falling body in falling from a height representing the gross head due to the lift

of water, friction, &c. The helical pump, on the other hand, appears to act by direct impulse, and in practice it is found that to a given height of lift it is only necessary to drive it at about half the speed which would be necessary for a centrifugal pump. In the case of tolerably high lifts, this is a decided advantage, and gives great facility for driving the pump direct.

The pump illustrated in the figures has a wheel or fan, B, 3 feet 6 inches diameter outside the blade C, and 6 inches deep, while the blades themselves are 6 inches square, which, minus a certain coefficient, represents the section of the stream of water which is made to flow through it.

One point in favour of this pump is that it gives a clear waterway of large area, a matter of importance in many cases, as, for instance, in the event of a leak, the pump has to draw from the bilge, and the screen or strainer happen to become damaged.

The patents secured for pumps fitted with slide valves are very numerous indeed, differing very little one from the other. A proof of this is again illustrated by Mr. Robert James Worth's patent secured in the year 1873. He claims the particular form of slide valve. On the outside of the pump he casts or attaches a chamber, or valve chest, in which ports are formed communicating with each end of the pump barrel, similar to those of an ordinary steam cylinder, by which the water or other liquid or semi-liquid is admitted into and exhausted from the pump; also a port, similar to the exhaust port of the steam cylinder, which port forms the suction passage to the working barrel; and a branch is also cast on the valve chamber, similar to the steam inlet on a steam cylinder, which forms the delivery from the pump.

Nearly covering these ports in the pump is a slide valve

having ports cast through it corresponding with those in the pump. Through these ports in the valve the liquid is admitted through the pump ports alternately into each end of the pump. The inventor specially recommends these pumps for heavy tar.

In the year 1873, Messrs. Ezra Cope and James Riley Maxwell, of Hamilton, Ohio, U.S., patented in England the double-acting ram or plunger pump illustrated in Figs. 91 and 92. Fig. 91 is a sectional elevation, and Fig. 92 an end view, with the back cover or bonnet removed. This pump is used for moderate lifts in mines, and consists in the manner of making a single solid plunger double-acting. This is done by providing the barrel of the pump, at or near its centre, with a stuffing-box for the plunger to work through, and placing each end of the barrel of the pump in connection with a set of inlet and outlet valve-boxes; the valve-boxes may be cast on or separately made and bolted to the barrel of the pump, as may be found most convenient. This pump consists of a single barrel A, which is provided near the centre with a stuffing-box B, for the plunger or ram, C, to work through, and each end of the barrel is in communication with a set of suction and delivery valve-boxes. These valve-boxes are, in this case, cast in one with the barrel. The valve-box cover has an air-vessel cast on it, and a communication is made between the delivery box and the air-vessel. D is a cover or bonnet, which covers the back end of the pump, and in which the ram or plunger works. E are three screws fitted with check or back nuts for tightening the internal gland.

Included in the same patent, Messrs. Cope and Maxwell, now Gordon and Maxwell, describe another type of double-acting ram or plunger pump:—In some cases it is desirable to expose the stuffing-boxes around the plunger of the

pump, especially in deep mining, to be more accessible, and to see if they are packed sufficiently tight to prevent leaking. For cases of this kind the barrel of the pump is

Fig. 92

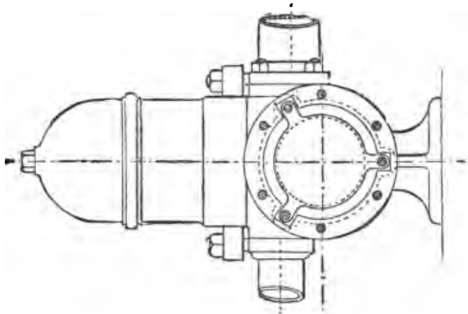
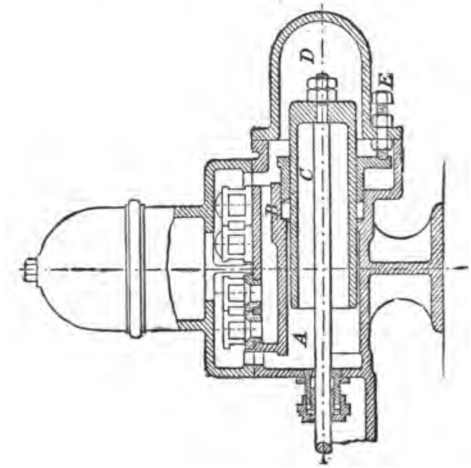


Fig. 91.



usually cast in two pieces and joined together by a connecting frame and bolts, or instead of casting the barrels separately they can be cast together by a framework

joining their two inner ends, and thereby forming the two barrels and framework in a solid piece.

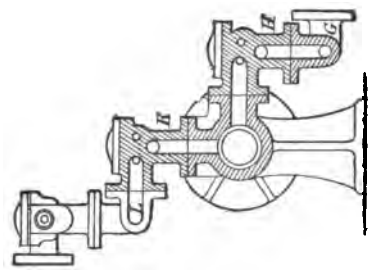


FIG. 94.

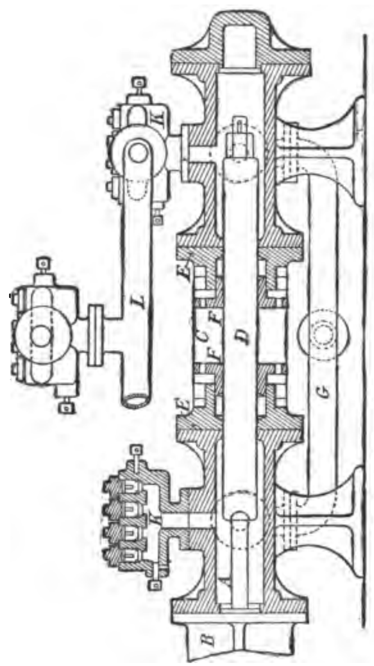


FIG. 93.

The inner ends of the barrels are provided with packing chambers and means for attaching stuffing-boxes, through which the plunger works; the valve-boxes may be cast to the barrels or separately made and bolted to them. The barrels of the pumps are made so that the inlet and discharge valve boxes may be placed on either side of the pump. Pumps of this kind may be constructed to work in a vertical or horizontal position. The piston rod of the engine is attached to the end of plunger, and works through a stuffing-box in a cover over one of the outer ends of the pump barrel.

Fig. 93 is a longitudinal section through the pump barrels and one of the valve-chambers, and Fig. 94 a cross section through the pump barrel and valve chambers.

A is the pump barrels; B the distance piece. The pump is double-acting and the barrels are joined by the flanged distance piece C. The plunger D works in the two pump barrels, and is packed in its middle by the stuffing-boxes E E, and glands F F; G is the receiving or suction pipe connecting the two pump barrels at their sides by the valve chambers H H, and J is the delivery pipe attached to the top of the pump barrels by the valve chamber K K. This pipe is provided with a valve-chamber L, to serve as a check valve.

In the same year (1873) we find a first class pump for compressing air; it was invented and patented by Mr. John Sturgeon, of Bolton-le-Moors, Lancashire. The great feature in this pump being the large area of the inlet valve, and the sudden action of it, as will be seen from the illustration, Fig. 95, which is a part sectional and part elevational plan. The pump is of the double-acting piston type, and consists of the working barrel A; piston B; pump-rod C. D is the inlet valve, fitting close round the piston-rod C, and carrying the stuffing-box and

gland E, and seated on the front of the bush F inside the cylinder. This bush contains openings G G, through which the air passes into the cylinder, as soon as the

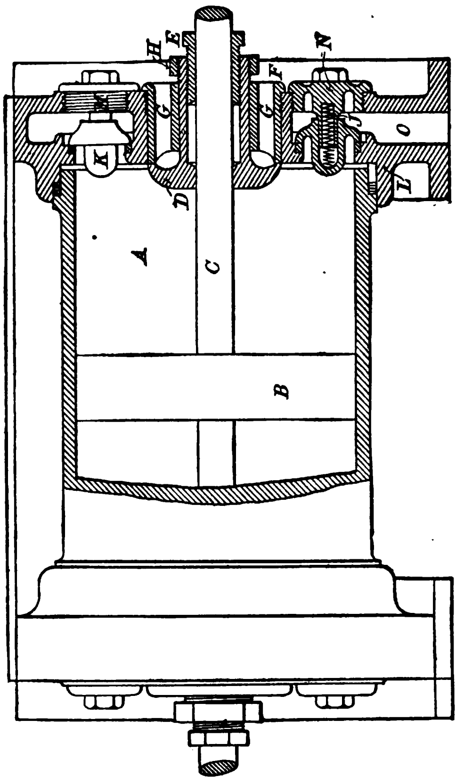


FIG. 95.

backward movement of the rod has drawn the valve open, by means of its frictional hold upon it, the amount of opening being determined by the position of the collar H, which serves the purpose of a stop.

J, K, &c. are a number of small delivery valves, which are placed in the hollow cover L, in a circle surrounding the central inlet valve D, and are closed in by the covers M, N, &c., which are screwed in at the front of the cover. These valves may be held against their seatings by springs, as at J, where needful, but when in a vertical position the springs will not be required, and are opened by the pressure of air produced in the cylinder by the forward movement of the piston B. The surfaces of the valves and the passages on the inside, facing the piston, are curved off so as to approach as near as possible to the form of the *vena contracta*, and thereby lessen the resistance to the passage of the air from the cylinder to the receiver. O is the delivery passage to the receiver. Several modifications of this arrangement are also claimed in Mr. Sturgeon's patent, all carrying out the same principle, namely, "placing the inlet valve in the centre of the cylinder cover of the compressor having its boss fitting closely round the piston-rod, the latter being free to slide through it, but the friction between the two being sufficient to draw the valve open as the piston begins to move away from it, and to push it shut as soon as the piston begins to move towards it."

A pump fitted with a very simple arrangement of clack valves is illustrated in Figs. 96 and 97. Fig. 96 is a sectional elevation, and Fig. 97 a sectional plan. This double-acting piston pump was patented by Mr. Cemer Thomas Colebrook, of London, in the year 1874. A and B are the suction valves; C and D the delivery valves. In the arrangement illustrated in the figure, one suction and one delivery valve are made of one piece of leather, and the other suction and delivery valve of another piece of leather; these four valves, or the two pieces of leather, canvas, or indiarubber, or any other suitable material, are stitched or riveted together; in another

arrangement the two suction valves A and B are made of one piece of leather, and the two delivery valves C and D of another piece; these four valves, or two pieces, are stitched or riveted together. In this manner Mr. Colebrook

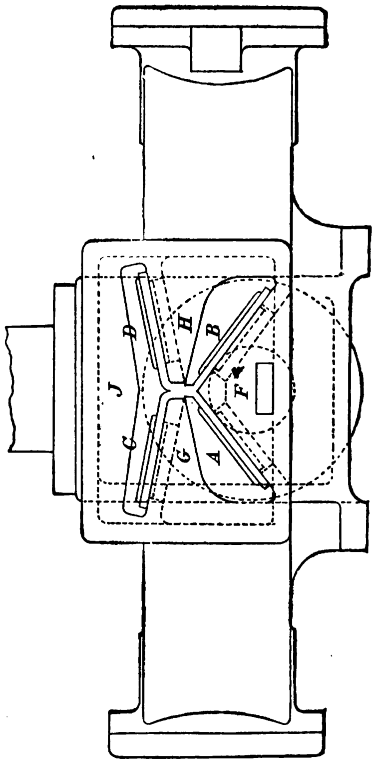


FIG. 96.

combines and forms the whole number of valves A, B, C, and D in one complete valve piece, and applies it simply by sliding it between the inwardly or transverse projecting parts F, G, and H, of the valve box or chamber J, and

retains it in position simply by the cover K of the valve box, as will be readily understood on reference being had to Fig. 97. Valves thus formed and applied are prevented

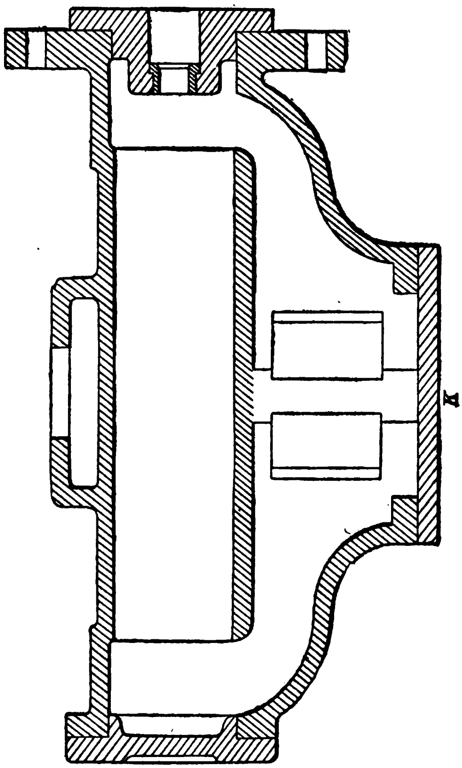


Fig. 97.

from shifting in any way, without the use of any of the usual fixing means, and have no motion except to ordinary lifting and falling, opening and closing, while at work. One of the important advantages derived from the use of

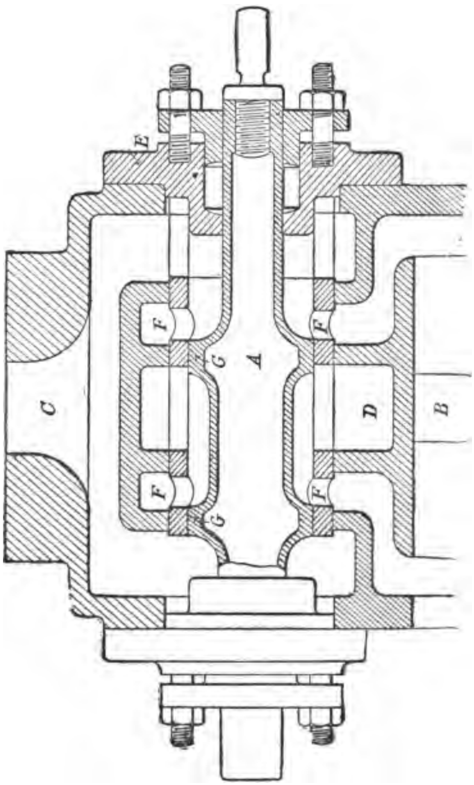
this arrangement is that they can be withdrawn from the valve casing immediately the valve box cover K is removed. When metal valves are used, the valves are all made separate, but joined together by means of two links and two spindles on which the valves turn.

Although piston valves have been patented many times previous to this date, we find one in 1874 by Mr. Joseph Evans, of Wolverhampton. Fig. 98 is a sectional plan of the valve and valve box, and part of the cylinder; the other part of the cylinder being similar to that of ordinary double-acting piston pumps. A is the piston valve, which, although it is in the patent shown solid, is made by the patentee hollow, as shown in the illustration. B is part of the pump piston. The pump piston B is represented as moving in the direction from right to left, and the suction is admitted through the suction branch C; D is the delivery passage from the valve box. It will be seen from Fig. 98, that the cylinder inside which the valve moves is itself a separate piece from the main casting of the pump and box, and is retained in its place by means of the cover E. The small openings, F F, are used for the working part of the cylinder, in preference to oblong openings, so as to retain a proper facing all round, and are used for the ends beyond the working part, so as to retain an equal distribution of metal round the cylinder. The collars or faces, G G, of the valve A are the same distance from the outer edge of one port as from the outer edge of the other port, but slightly farther apart from the inner edge of one collar to the inner edge of the other collar than the inner edge of one port to the inner edge of the other port, so as to prevent the liquid in the pump from being trapped as the valve collar is travelling over the port. This pump, when fitted to a steam cylinder, is furnished with a very simple reversing gear, so as to turn

the suction into delivery and the delivery into suction, when tar is the fluid to be pumped.

All the centrifugal pumps we have so far described

FIG. 98.



have had an impeller only, and not fitted with any guide blades; but in the year 1874, Mr. Frederick Arthur Paget, of London, patented a pump of this description, communicated to him by Messrs. August Christian Nagel and

Reinhold Hermann Kaemp, of Hamburg. Figs. 99 and 100 illustrate a centrifugal pump with a horizontal spindle and an eccentric casing. Fig. 99 is a cross section

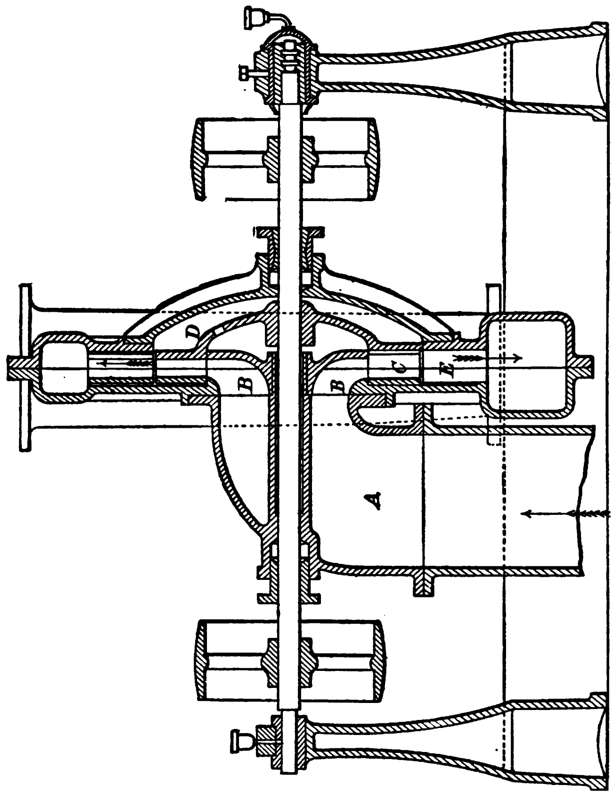


Fig. 99.

and Fig. 100 an elevation. The water ascends up the suction-pipe A, and is gradually guided or led into the revolving wheel C, by means of the directing plates B; from the revolving wheel or fan C, it is projected by

centrifugal impulse into the vanes of the concentric guiding wheel. In this case the directing plate B is fixed, but it is sometimes made adjustable, so as to regulate the

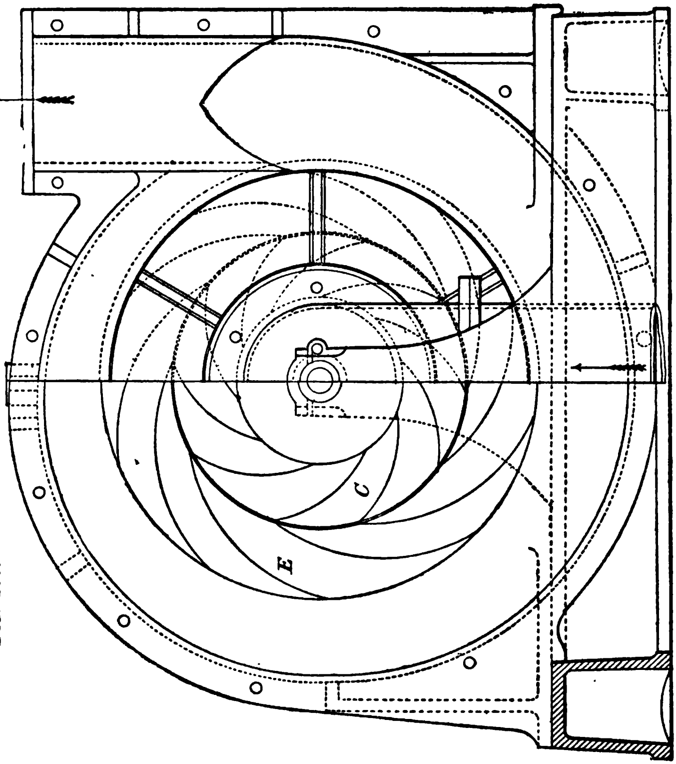


FIG. 100.

quantity of the fluid conducted into the pump. In such instances, and with centrifugal water pumps, it replaces the foot valve, and serves to fill the pump, while it also allows such pump to be placed direct into the outlet pipe

without any outer casing. The directing plates are shaped to the section known as the "*contraction curve*," and it is clear that it may be adapted to any known form of centrifugal pump or fan.

The fixed wheel or casing E is fitted concentrically to the outer periphery of the revolving wheel, and the proportions and directions of the series of cells of which such fixed wheel or casing consists are adapted to the absolute velocity of the issuing fluid. The same flows out of the cells in a radial direction when no eccentric outer casing is employed, and more tangentially when such an eccentric casing is applied as in Fig. 100. Such a concentric fixed wheel or casing as described may be applied to any appropriate known form of centrifugal pump.

When the spindle is vertical the pump is fixed in an iron or brick well, the outlet from which is placed at the lowest level to which the water in the outlet channel is ever likely to fall. The pump is hung on its spindle by a gun-metal bearing always accessible, this of course does away with the footstep; all the bearings of the different parts have conical seats, and the impeller can be taken out and replaced without emptying the pump well. No suction and delivery pipes are used. The outlet from the well is fitted with a self-acting back pressure or sluice valve, to prevent the water from flowing back when the pump is standing.

A greatly improved modification of Trevithick's "Temporary Forcer" or continuous flow pump was invented and patented in England about the year 1875, although it is illustrated in "Die Pumpen," written by Mr. Frederich König, and published in 1869. It is illustrated in Fig. 101 which is a sectional elevation. It consists of a suction working barrel A, and a delivery barrel B. C is the suction pipe; D the delivery pipe; E and F are the suction and

delivery buckets. The pump rods H and J, are coupled together to one crosshead K, and this again to a piston rod L, or connecting rod, as the case may be. G is the back cover, which also forms the connecting pipe or com-

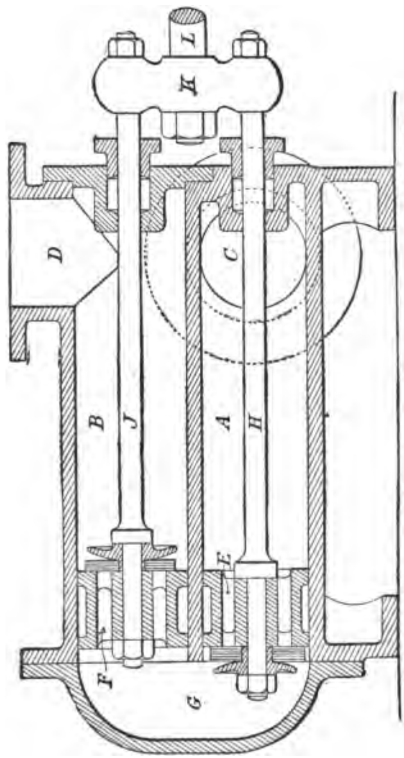


Fig. 101.

munication between the two barrels. There is a great advantage in this continuous flow pump, namely,—the water has a flow in one direction without meeting any obstacle, and it has an easy flow which reduces the friction,

but it has the great objection that the strain on the crosshead is alternate; however, this can easily be got over by making a large suction barrel in the centre, and one delivery barrel on each side, each of which should have

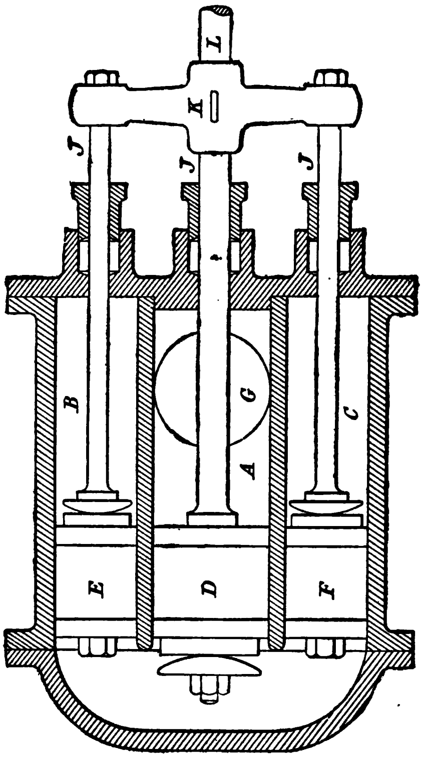


FIG. 102.

one-half the area of the suction barrel, and the three pump rods coupled to one crosshead, as shown in Fig. 102, which is a sectional plan. A is the large suction barrel, between the two small delivery barrels B and C, each of the

small barrels being half of the area of the large barrel A; D is the suction bucket; E and F the delivery bucket; G the suction pipe. The delivery pipes are not shown, being provided on the top of the delivery barrels, and joined

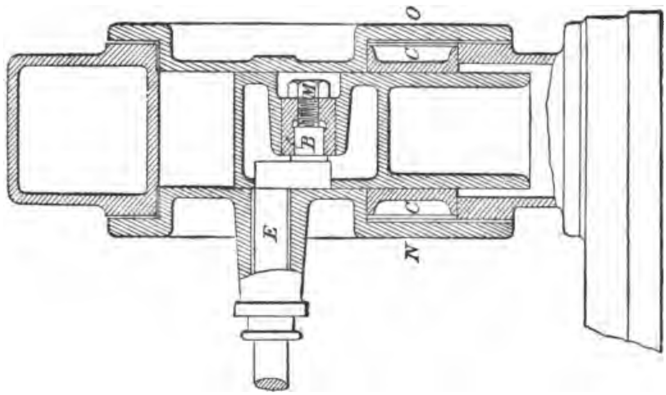


FIG. 104.

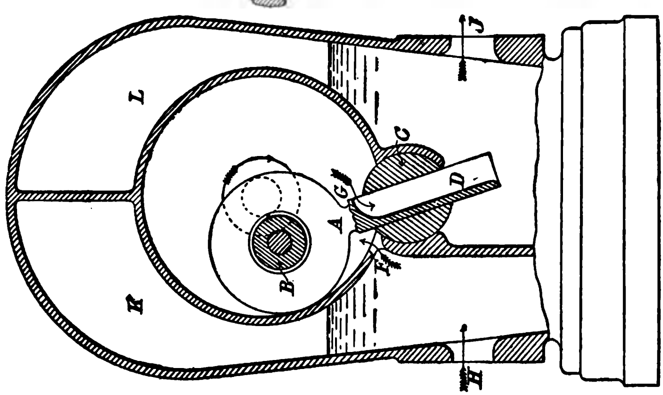


FIG. 103.

together in one branch. The three pump rods J J J, are coupled to one crosshead K. L is the steam piston rod.

In the illustrations Figs. 103 and 104, is shown a some-

what novel pump, patented in the year 1875, by Mr. Bartrum. The action of the pump may be described as follows:—The crank shaft E is caused to rotate, and in doing so carries the piston A round with it against the inside of the cylinder, the centre travelling round the dotted circle in the direction of the arrow. The tail-piece D of the piston A travels up and down in the rocking guide C. By this action on one side of the piston, the water is drawn in at an opening F in the cylinder, and on the other side, the water that had been drawn in during the previous revolution is forced through the passage G in the tail piece D, and so on, continuously giving a constant delivery. H is the suction inlet and J the delivery outlet. K forms the suction air-vessel or vacuum vessel, and L the delivery air-vessel. It will be observed that the suction and delivery passages are never open to one another, and so there is no *slip*. The adjustment between the piston A inside the cylinder is made by turning the small eccentric on the crank shaft pin, and fixing it with the nut M. The working guide C is kept at a constant working fit in its bearings by the pressure of the water on the discharge side of the piston B. The polishing action of the piston against the inside of the cylinder covers N and O, is said to maintain a perfectly smooth surface. Any play between the cylinder covers N and O and the ends of the piston A, can be taken up at once by reducing the thickness of the joint between the cylinder and the cylinder covers. In some cases this joint is made self-acting by placing a *saucer* plate between the ends of the piston and the inside of the cylinder cover, to the back of which plate the water is admitted from the air-vessel, thus keeping the working parts always in contact.

In 1875, we find a form of rotary pump constructed by the McFarland Pump Co., Limited, London, which

has been tested against both high and low lifts with very satisfactory results. Figs. 105 and 106, are respectively a longitudinal and transverse section of one of these pumps, adapted for lifts up to about 60 feet; while Fig. 107

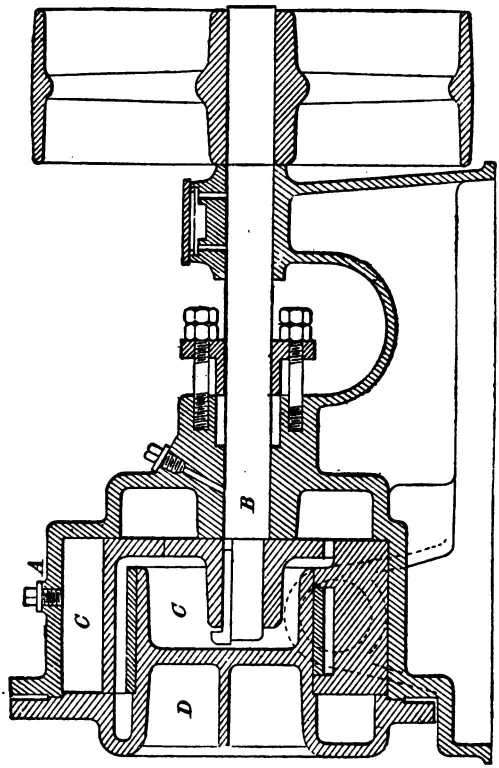


Fig. 105.

shows the slight modification of construction adapted for high lifts.

Referring to Figs. 105 and 106, it will be seen that the pump consists of an outer casing, A, into one side of which

a shaft B enters eccentrically, this shaft having keyed upon it a drum C, of such diameter that it just touches the interior of the casing on one side, as shown in Fig. 106. On the cover D, which closes the outer casing on the side

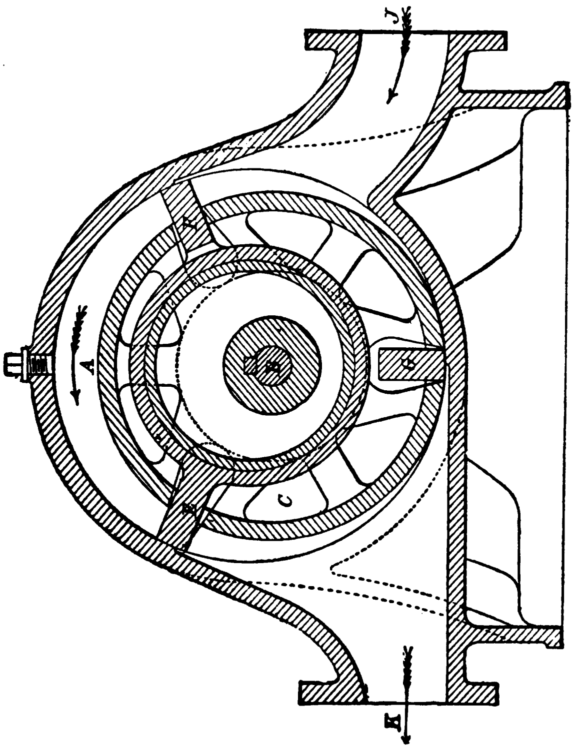


Fig. 106.

opposite to that on which the shaft enters it, is formed a long boss, C, which is concentric with the casing, and which passes into the driving drum C already mentioned as being keyed to the shaft, B. On this boss are mounted

three arms, E, F, and G, which are capable of revolving freely, and which pass out through three slots formed to receive them in the driving drum. The outer extremities of these arms fit against the interior of the casing, as shown in Fig. 106.

It will be seen from the illustrations, that as the shaft revolves in the direction of the arrows, the driving drum carries round with it the arms turning on the boss of the cover, and each arm, as it passes through the upper third of its revolution, sweeps before it a charge of water, filling the upper part of the pump. In the earliest McFarland pump two working chambers were used, each chamber being fitted with two arms; as now made, however, but one chamber is employed, this being fitted with three arms, as explained. It will be seen by referring to Fig. 106, that, owing to these arms only acting through the upper third of their revolution, the amount of their sliding movement through the driving drum, when exposed to the pressure of the water, is very small, the chief sliding movement taking place during the remainder of the revolution, when the arms are in equilibrium. The pump thus works with but very little friction, and the flow is very regular.

In cases where lifts of over 60 feet have to be dealt with, it is preferred to increase the bearing surface of the arms against the driving drum, by the introduction of semi-cylindrical steel bearing pieces, H, shown in Fig. 107.

In the pump for moderate lifts the main pump casing is cast in one piece with the bed-plate and standard carrying the outer bearing of the shaft. In the case of some of the high-lift pumps, on the other hand, the casing is made independent of the bed-plate, for convenience of arranging the gear to suit special circumstances. These pumps have been tested against lifts of from 5 feet to 168 feet. Whilst

working against 99 feet an efficiency of 58 per cent. has been obtained, the pump running at 133 revolutions and lifting 135 gallons per minute, the pump being 4 inches diameter. With a lift of 150 feet and a speed of 120 revo-

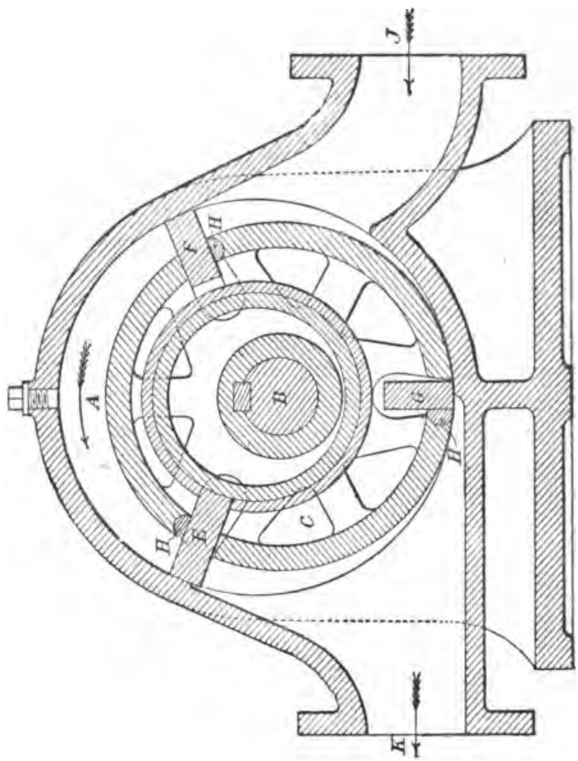


Fig. 107.

lutions the same size of pumps has delivered 195 gallons per minute.

A very unique double-acting piston pump for light pressures is shown in Figs. 108 and 109. This pump was

Fig. 108.

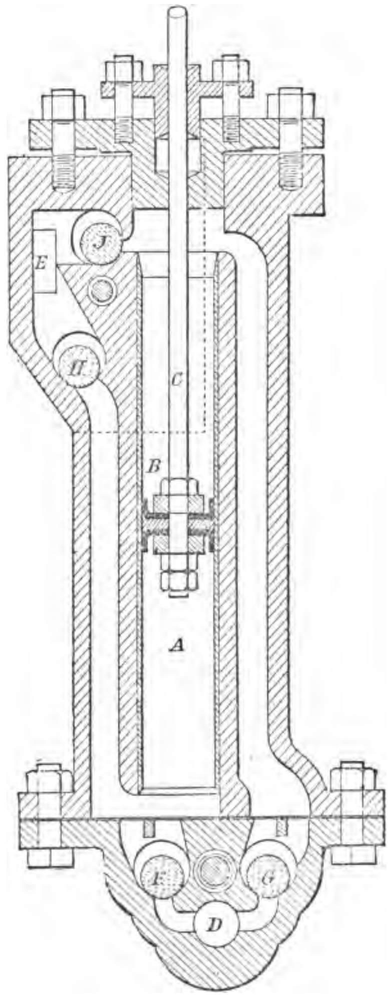
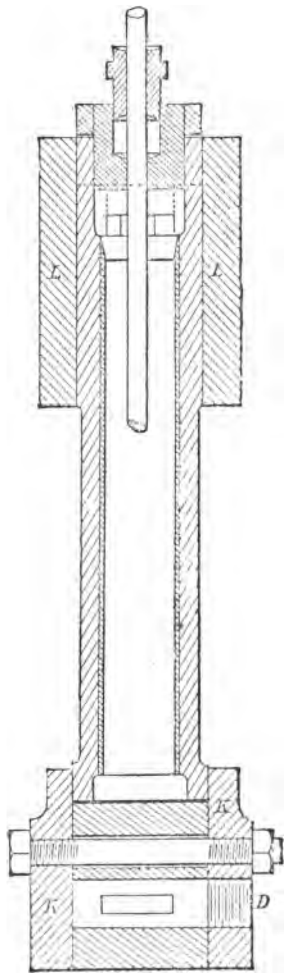


Fig. 109.



invented by a Mr. Rider, of United States of America. The first of this class came to England fitted on one of Mr. Rider's hot air engines, which was exhibited at the Royal Agricultural Exhibition, held at Birmingham, in the year 1877. It consists of the working barrel A; the piston B; C is the pump rod, D the suction inlet, E the delivery; F the suction-valve for the bottom of the barrel, G for the top of the barrel; H the delivery valve for the bottom of the barrel, and J for the top of the barrel. K K are the covers for the suction-valves, L L for the delivery valves. The valves are simply an indiarubber cord cut to the required lengths. It will be seen that each set of valves are easy of access, the covers being secured by a single bolt stud provided with nuts at each end.

An excellent pump for ships' purposes is shown in Figs. 110 and 111, and was introduced by Messrs. Stone, of Deptford; it is a modification of the Dounton pump, which the author has already described. The inventors claim that this pump only costs about half that of Dounton's pump to give the same delivery; that is to say, a 4-inch Blundell pump would throw as much per revolution as a $5\frac{3}{4}$-inch Dounton of the usual stroke, and so on, for other sizes; thus this pump has a delivery equal to three common single-acting pumps of similar stroke and diameter.

This invention consists in employing three or more pistons working in one pump barrel, which pistons are so worked or operated as to alternately approach to and recede from each other by means of two cranks working two crossheads or connecting rods which are attached to the pistons. The valves are so arranged that the water can give access to the space between the pistons by passages outside the pump barrel. The pump head may be fixed, or may be so arranged as to form or act as a delivery valve, or in some it is dispensed with entirely.

The delivery from the second piston may in some cases be so arranged as to discharge through to top piston by means of a trunk piston-rod closed by a valve.

FIG. 110.

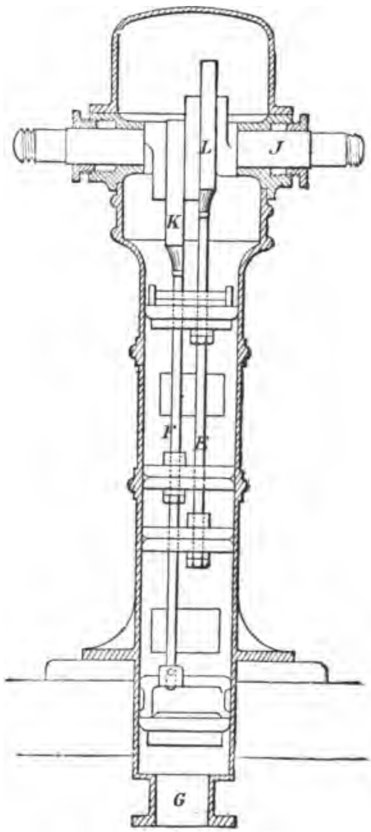
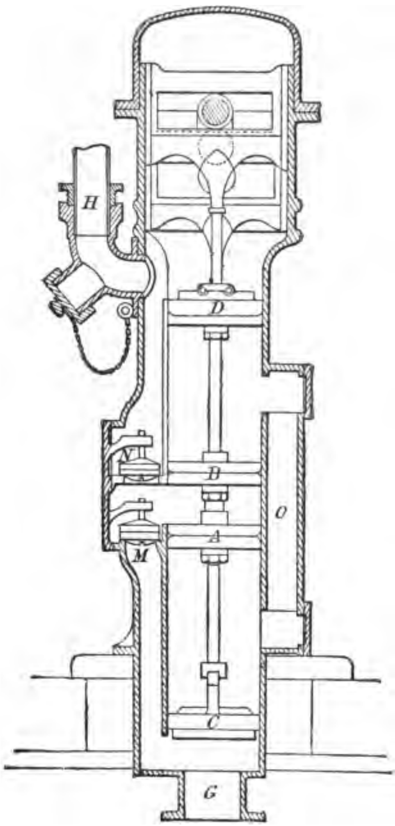


Fig. 110 is a sectional elevation and Fig. 111 a sectional end view.

Fig. 111.



In this arrangement two pistons A and B, and two buckets C and D, are employed. The piston A and the

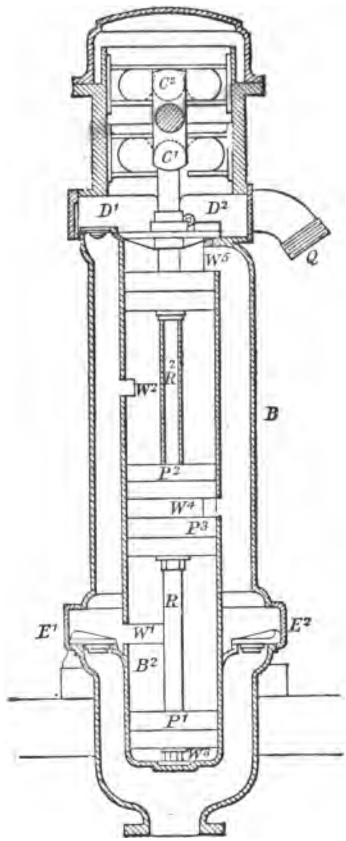
bucket D are secured to the pump-rod E; and piston B and bucket C to the piston-rod F; G is the suction pipe, H the delivery pipe; J is the crank shaft actuating the two cross-heads K and L; M is the suction-valve admitting water between the two pistons A and B, and N is the delivery valve; O is a passage communicating between the two buckets C and D.

The action of this pump is as follows:—Supposing the pump to be full of water or any other liquid, and the crank shaft J moved round, then, when piston B and the bucket C are moved upwards, the water enters through the suction pipe G, through the suction-valve M, into the space between the two pistons A and B; at the same time the piston A and the bucket D are moved downwards, causing the piston A to deliver water through the passage O into the space between the piston B and the bucket D, and also forcing the water through the bucket D into the delivery pipe H, and the water between the pistons A and B is delivered through the delivery valve N into the rising main or delivery pipe H. From this description it will be seen that there is a constant delivery.

A modification of this ship's pump is represented in illustration Fig. 112. In this arrangement it will seen that there are four pistons instead, as in the previous one, of two pistons and two buckets. The illustration is a sectional elevation. Messrs. Blundell and Holmes patented this pump in 1876, and claim the advantage on account of its accessibility in the event of it getting choked or in case of repairs being required, as all the valves can be got at from the outside and no buckets are used. Another advantage is the small nnmber of parts, the valves being reduced to four, no foot-valve being required, and only two pump-rods and slides are used. As the lower chamber is always charged with water, readiness of action is ensured.

As will be seen in the illustration, there are four pistons carried upon two separate rods working side by side

Fig. 112.



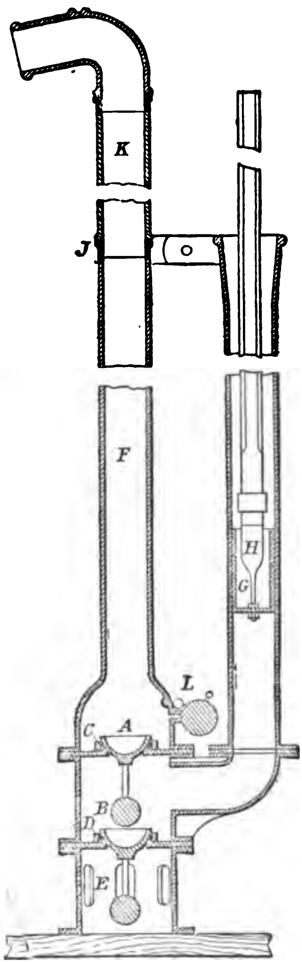
(only one of which is shown) through stuffing-boxes or hydraulic leathers in the pistons, and as is usually in

Dounton's pump. In Dounton's pump, however, when the valves get choked, the pump cover has to be lifted, and the whole of the interior drawn out in order to clean or repair them, but in this pump the valves are accessible through doors E^1, E^2, D^1, and D^2, and therefore the interior will only need removal when the piston leathers require renewal, which is very seldom.

The action of the pump will be readily understood from the following description. Upon the crank shaft being turned as indicated by the arrow, the crank C^1 lifts the pistons P^1 and P^2 simultaneously by means of the rod R^1, and at the same time the pistons P^3 and P^4 are forced downward by the rod R^2 and the crank C^2. The spaces under P^1, between P^2 and P^3, and above P^4, will then be filled by the water lifting the valve S, and passing through the passage B and the ports W^3, W^4, W^5, and at the same time the water assumed to be between P^1 and P^3, and P^2 and P^4, will be discharged through ports W^1 and W^2, and up the passage B^1 through valve D^1 and out of the nozzle O. Upon the rotation of the crank shaft being continued, the action of the pistons will be reversed, and like results will follow; the filling and discharging of the spaces being alternately as the pistons approach or recede from each other.

A German farm pump was first manufactured by Messrs. Jacab and Becker, of Blücher Platz, Leipzig, in the year 1877. Fig. 113 shows the form of pump which was specially wanted by German farmers. It is quite simple in design, and is so arranged that the parts are easily accessible. It will be seen that the valves A and B are hemispherical, and are provided beneath with a weighted stem to keep them vertical and fair on their seats, which consists of rubber rings C, held by angle iron rings D. The inlet chamber E may be bolted on to a wooden base,

FIG. 113.

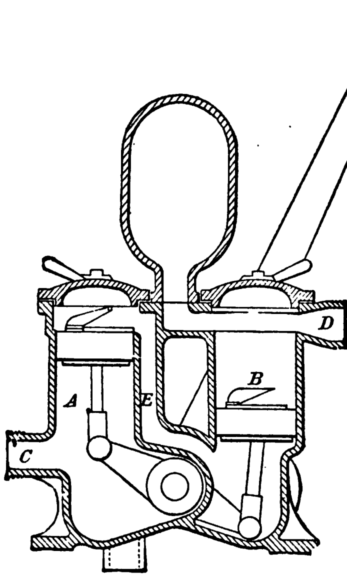


and if desired can be surrounded with an interception formed of plaited osiers, to prevent solid matters from entering and choking the pump; of this, however, there is little danger, as whatever passes the inlets can be carried up through the valves. The pump barrel is kept steady, by means of an adjustable attachment, to the ascending pipe shown at F, consisting of a bolt passing through slots in the connecting bars. The plunger is without packing, and is made of the form shown at G, a plate H being cast into it for connecting it to the pump-rod. The top of the fixed length of ascending pipe is made taper, with a semicircular groove running round it, shown at J, and within which a rubber ring is placed to make the joint with the socket at the next length of pipe. The same form of joint is used for each section of pipe, as indicated on the length K. In order to empty the ascending pipe, an outlet is provided at L,

consisting of a valve kept down by a heavy weight, but which may be raised by a cord.

In illustration Fig. 114 is shown the construction of a continuous flow pump of an uncommon construction, patented by Mr. C. F. Amos and Mr. H. W. R. Smith, of Hull, in the year 1878. The illustration shows the con-

FIG. 114.



struction so clearly, that but little description will be required. The pump consists of two parallel cylinders or working barrels A and B, the lower end of A communicating with the suction inlet C, and the upper end of B communicating with the delivery pipe D, while the upper end of the cylinder A communicates with the lower end of B by a passage E formed in the cylinder casting as shown.

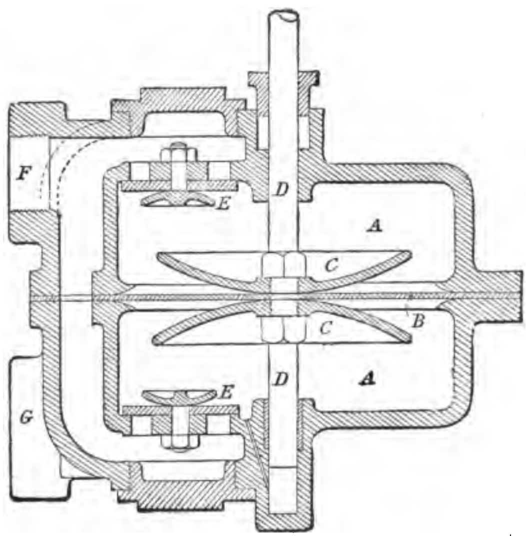
Except for the communication afforded by the passage E, the two cylinders are shut off from each other by a partition. Each cylinder is fitted with a bucket having a valve opening upward, and these buckets are coupled to arms on a rocking shaft, the arrangement being such that one bucket falls when the other rises, and *vice versa*. The rocking shaft is packed by a cup leather where it traverses the partition between the cylinders, while it passes out of the pump casting through stuffing-boxes and is fitted with hand-levers, or with arms driven by a crank and gear, according to the size of the pump and the purpose for which it is to be used.

It will be seen that as the pump is worked, the capacity of the space enclosed between the two buckets is alternately enlarged and reduced, it being at its minimum when the parts are in the position shown in the illustration. The two bucket valves thus act as suction and delivery valves respectively, while, moreover, as the left-hand bucket draws from the suction-pipe during its rising or up-stroke and at the same time delivers through the other bucket, the right-hand bucket also delivering during its rising stroke and at the same time drawing through the left-hand bucket, the delivery is continuous, and the current of water being always in the same direction a high efficiency is attained. The valves and buckets, it will be noticed, are very readily accessible, and altogether it is a very good, though not new arrangement.

Although Mr. J. L. Norton, in his patent specification dated 1861, when describing his single-acting diaphragm pump, states,—" The apparatus may be made double-acting by dispensing with the passage through the disc, and adopting supply and exit pipes with suitable valves for each chamber," we find that Mr. G. V. Fosberg secured a patent for a similar double-acting diaphragm pump in the

year 1878. One of these pumps was exhibited at the Tynemouth Exhibition. This pump is illustrated in Fig. 115, which is a sectional elevation. A A are the top and bottom parts of the body, between which is secured a sheet of flexible indiarubber, B, dividing the pump into two parts; on each side of this rubber are iron shields, C C, secured to a rod, D D, guided at both ends; one end of the

FIG. 115.



rod is attached to a handle in the usual way. E E are the suction valves, F the suction pipe, G the delivery pipe; the delivery valves being on a line with the suction valves are not shown in the illustration. The suction and delivery of water or any other kind of fluid is caused by alternately raising and depressing the indiarubber diaphragm. These pumps are intended particularly for ships, boats, fishing

smacks, &c.; they are simple in construction, and little liable to derangement.

We find in the same year (1878) another air-compressing pump, patented by Mr. Sturgeon. It consists in the means of actuating the inlet valve so as to ensure certainty of action in opening the valve, no matter at what speed the pump may be running, together with an improved arrangement of the parts of the pump in connection with the arrangement of the inlet valve or valves. For this purpose Mr. Sturgeon places the seat of the inlet valve or valves in the plungers, and applies the valves to them so as to move to and fro therewith, in such a manner that the valve may remain stationary while the piston is moved away from it to the extent of opening allowed, thereby opening the valve at the commencement of the backward or admission stroke. In this case, the piston rod or connecting rod is directly attached to the piston, the valve being loose and free to move independently to and from its seat therein; but if sufficiently retarded in such independent movement by its own inertia, the pressure of air against its surface, and the momentum previously imparted to it, to allow the movement of the piston which effects the opening or closing of the valve to take place first, the valve then, in its open or closed position, accompanies the piston through the remainder of the stroke.

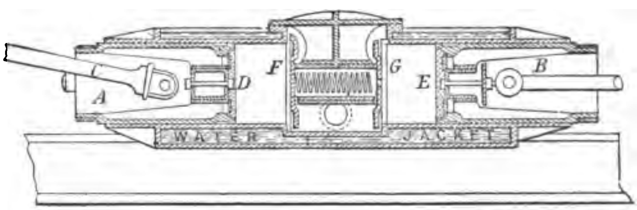
In another arrangement, two single-acting air-compressing pumps are fixed with their axes in one straight line, so that the two pistons or plungers may be fixed on the one piston rod.

When the cylinders are used as above described, the plungers may be connected together on one piston rod, and the two valves also connected together; but there must be just sufficient difference between the distance of the seats apart and the distance of the valves apart as to allow for

the necessary lift or opening of the valves. In this case the seat of one valve acts as a stop to regulate the lift or opening of the other valve.

Another arrangement is shown in Fig. 116, which is a longitudinal section. A and B are the plungers, coupled together by outside rods, and actuated by the connecting rod C. D and E are the suction-valves, seated in the plungers A and B. F and G are the delivery valves, one

FIG. 116.

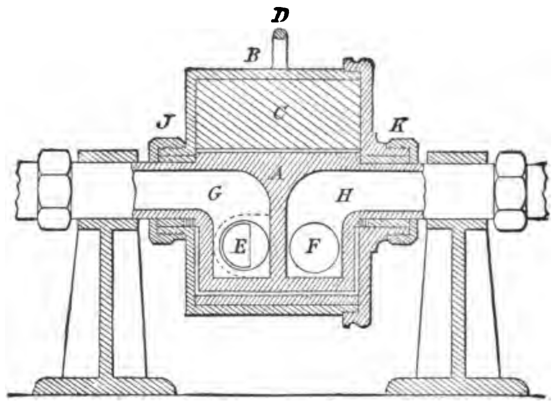


made to slide on a boss on the other, and a spiral spring introduced inside the bosses to keep the two valves on their faces when not in action.

The American 'Sanitary Engineer,' 1883, illustrates a pump called "The Invincible," the principle of which was claimed to be new at that time. This pump is illustrated in Fig. 117. It consists of a valve section or chamber A, which is stationary, with hollow ends, which extend through each end of the pump cylinder B, and the cylinder itself, which is pivoted on the protruding ends of the valve chamber A, and to which is attached the sector piston C. This sector divides the cylinder lengthwise into two chambers. The rocking of the cylinder B by the handles D, gives alternate vacuum and discharge in each chamber. There are four valves, two suction, E, and two delivery, F. The packing in the valve section consists of strips of

leather let in flush, or nearly so, with the metal. The sector C is also packed in the same way. G is the suction-chamber, and H delivery chamber. J, K, are two packing

FIG. 117.



glands, making the joint between the valve sector A and the cylinder B.

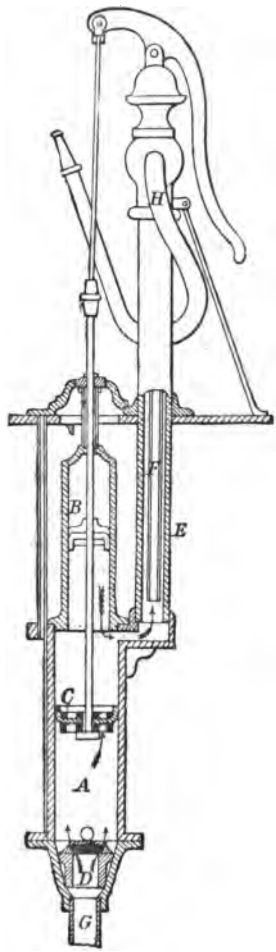
This pump was patented in this country in the year 1880.

A hand force pump, known in America by the name "Red Jacket," was patented in that country, in the year 1881, by John P. Martin, Cincinnati.

The illustration, Fig. 118, represents this pump, adapted to any well or cistern, and for all purposes; it is arranged so that the valves and pistons can be easily taken out, if necessary, for repairs, without removing the pump, standard barrel, or going down into the well. A is the pump barrel; B the differential piston, which is half the area of the bucket C; D is the suction-valve. The column or standard E forms the air-vessel, and F is the dip-pipe

or delivery pipe, G the suction pipe, and H the delivery hose, which is coupled on to the spout when the pump is used for fire purposes, or watering gardens, &c. One great advantage in this pump is that there are no stuffing-boxes and glands to keep tight. It will be easily seen that this pump is a modification of the previously described bucket and plunger type.

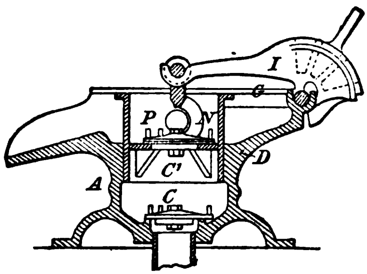
FIG. 118.



A very useful and compact little lift pump, illustrated by a sectional elevation, Fig. 119, was patented in the year 1882, by Mr. Henry C. Langrehr, of San Francisco, California. It consists of a body casting A, provided with an internal cylindrical bearing D, and a chamber furnished with a spout or shoot; the chamber is furnished with a rim G, which forms a continuous bearing for the working lever I, and provided at its base with a suction-valve, C. P is a hollow plunger fitted with a delivery valve C^1 and connecting link N. The valves

are of the lifting disc type, guided above the seats by means of projecting pieces round the circumference of the valve plates.

FIG. 119.



We now come to a simple and ingenious air compressor of the ram type, which was patented in the year 1883 by Mr. Frank Walter Scott. The invention has reference to that class of air-compressors in which the air is compressed in separate stages, such apparatus being constructed with one or more chambers, having suitable valves connected therewith for the admission and retention of the air to be compressed.

In Fig. 120, A shows an outer cylinder which is fitted with a stuffing-box and gland in which leather or any other suitable packing can be placed. B is the plunger, which is caused to work up and down in the cylinder A, by which means the air is drawn in on the upstroke through the valve C, and is compressed on the downstroke into the chamber D, through the valve E. On the second upstroke, the compressed air being retained by the valve E is forced through the valve V, into the pipe L, which communicates with a receiver or chamber M, or other suitable receiver. The heat caused by compression is kept down by water running in at F, into the chamber

plunger, and the connection between it and the chamber D G and out at H. The pipe L also forms the guide for the

FIG. 120.

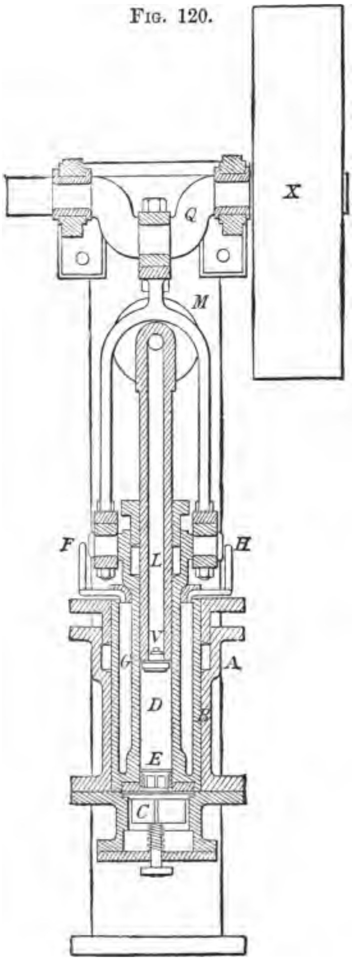
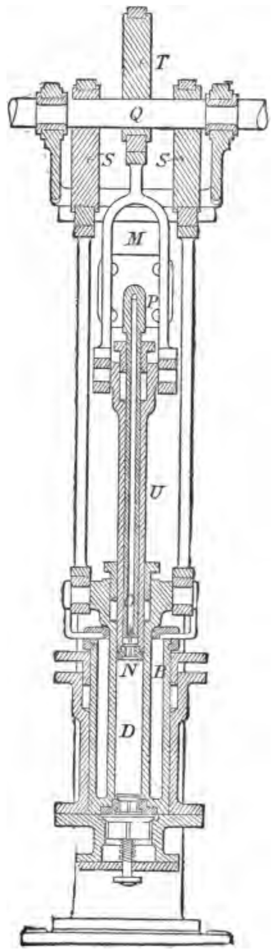


FIG. 121.



plunger, and is kept tight by a stuffing-box as shown. By means of the arrangement above described the pressure of air under the first plunger may be very moderate, while in the reservoir or chamber M it will be very great. X is the driving drum or pulley for actuating the crank shaft Q.

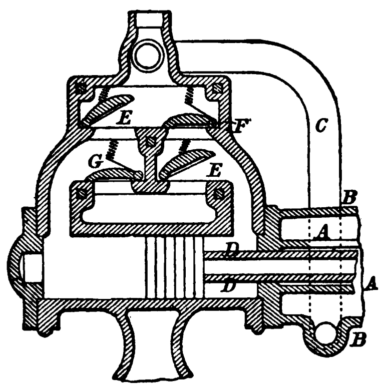
Fig. 121 shows the method of obtaining another stage of compression on the same plan. The operation is precisely the same as that in Fig. 120, except that the fixed pipe L is replaced by the plunger U, which plunger being caused to move in the opposite direction to the plunger B, on its down stroke receives and retains, by means of the valve N, the air partly compressed in the chamber D, and on its up-stroke compresses the air finally through the valve O, in the fixed pipe P, into the reservoir or chamber M, or other suitable receiver.

The motion necessary for actuating these plungers in the proper directions are obtained by cranks or eccentrics set in suitable relative positions, the whole being actuated by any convenient means applied to the shaft Q. S S are the eccentrics for working the plunger B, and T is the eccentric for working the plunger U.

The pump shown in Fig. 122 is of the ordinary double-acting piston type, with all the valves placed above the working barrel, so as to secure the working barrel always being full, the peculiarity of this pump being the valves. This pump was patented in England, August 1884, by Mr. L. B. Carricaburu, of New York, U.S.A. With direct-acting steam-pumps, to obviate the necessity of packing the piston, Mr. Carricaburu employs a tube, A A, connecting the two pump and steam cylinders; this tube he surrounds by a second tube B B, the annular space between the two serving as an air-vessel; this space he connects by a tube, C, to the water delivery-pipe. A tube of copper or brass, D D, is fitted on the piston-rod, and is capable of

being replaced when worn out. The tube he sometimes splits in the centre, and introduces a packing. Babbit-metal may be poured into the rough casting in the space surrounding the piston-rod. The valve chamber opens on both sides, to allow for facing off the valve seats. The valves E E lift bodily from their seats, and also swing up at an inclination. This is accomplished by having the trunnions F F of the valves attached to radial arms G G; these arms are wound at one end in spirals round the trunnions,

FIG. 122.



the other ends terminating in helices surrounding the studs, thus allowing for the lifting and bending movements.

In the year 1884 Mr. Joseph Armitage Wade and John Cherry patented the centrifugal pump illustrated in Figs. 123 and 124. Fig 123 is a sectional elevation, and Fig. 124 a sectional end view. It consists of an ordinary impeller A, with taper sides, furnished with a screw B, on each side; these screws are right and left handed and made to fit in the screw chambers, the external diameter being equal to the centre openings for the inlet of the

water; C is the spindle on which the impeller and screws are firmly keyed, it carries the driving pulley D: the

FIG. 123.

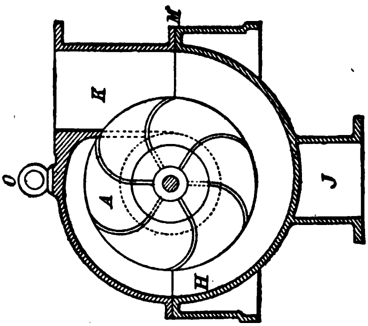
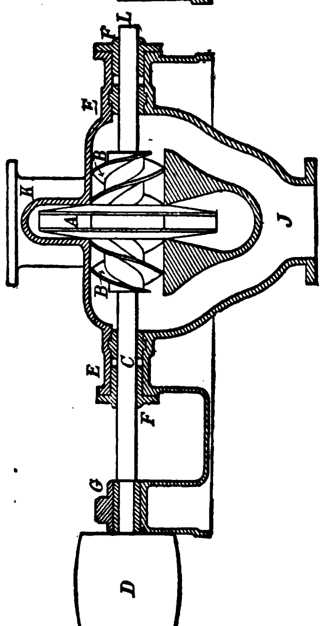


FIG. 124.



spindle works through two stuffing-boxes E E, and glands F F, and an ordinary bearing G, on the inside of the driving pulley; H is the casing, J the suction-branch, and K the delivery branch. The whole of the pump is cast in one with a substantial bed-plate.

The joint in the casing, giving access to the impeller for clearing and repairs, is made at L M.

The screws in the inlet are 6½ inches in diameter, having each three threads. By careful experiments it has been found that a pitch of 9 inches for the screw gives the best results in a 6-inch pump.

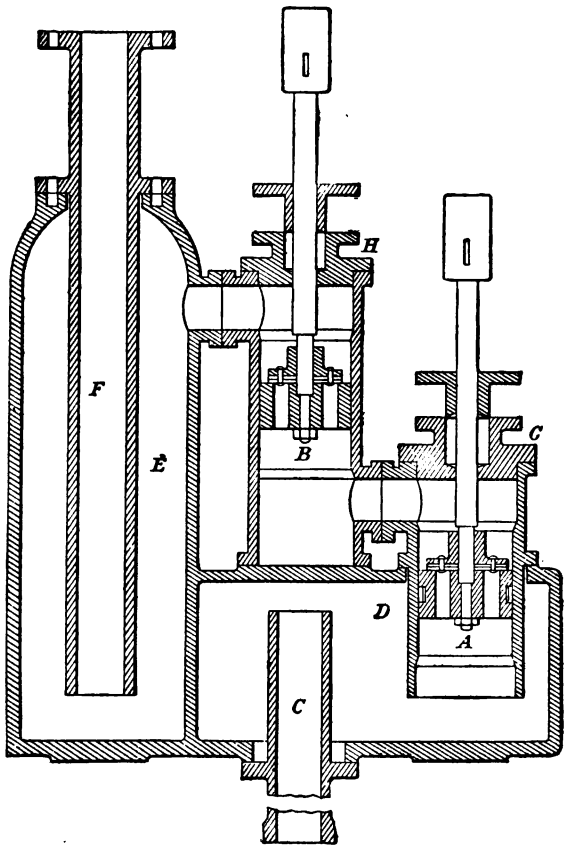
From the elevation, Fig. 123, it will be seen that there are six vanes in the impeller, which are curved backwards; they are similar in shape to those in Gwynne's pump.

The pump illustrated has 6-inch suction and 6-inch delivery pipes, the impeller is 14 inches in diameter and 1 inch wide, that is 1 inch opening and 1½ inch width of case. A stop N is provided across the top of the casing, to prevent the water from rotating in the casing. It is said to deliver from 10 to 15 per cent. more water than ordinary centrifugal pumps.

Mr. Henry Davey, of Leeds, in the year 1885 patented an excellent double-acting pump. The invention relates to a construction of a double-acting pump arranged in such a manner as to simplify the valves and to give ready access to the wearing parts, as will be seen from the illustration, Fig. 125, which is a vertical section of this class of pump. In all cases Mr. Davey employs two working-barrels or cylinders, each fitted with a bucket or piston having a passage through it covered by a valve opening in the direction of flow, and the suction inlet to the pump is so arranged that there is always liquid ready for starting the pump into action without the necessity for the charging with liquid which is required in many pumps.

Referring to Fig. 125, A and B are the two working barrels, the buckets of which, being worked from opposite

Fig. 125.



revolving cranks or from opposite ends of an oscillating beam, are always moving in opposite directions; that is to

say, when the bucket A is ascending, the bucket B is descending, and conversely. The suction pipe C opens into a suction air-vessel D, with its mouth considerably above the bottom of D, so that there is always retained in the vessel sufficient liquid to charge the first barrel A when the pump is started into action. The second working barrel B, which on starting is primed from A, discharges into the air-vessel E, from near the bottom of which the delivery-pipe F ascends. The buckets and the valves are readily accessible on removing the covers G and H of the two working barrels.

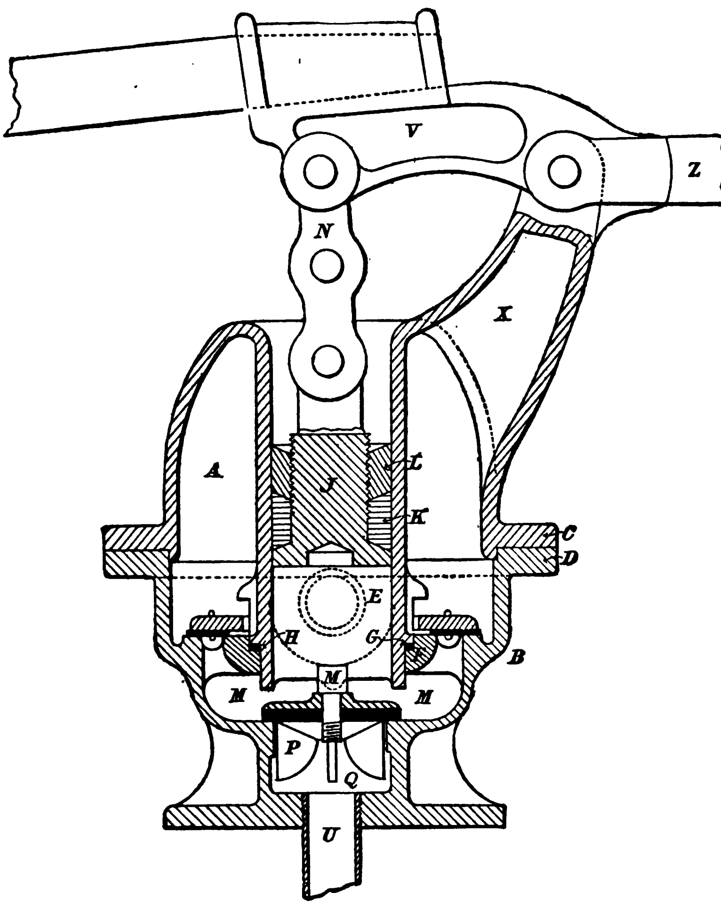
The action of the pump may be thus described. As the bucket A ascends it draws the liquid below it, and discharges the liquid through the bucket of B which is descending. As the bucket of B ascends it draws liquid through the bucket of A, which is then descending, and discharges the liquid above itself into the air-vessel E. Thus, in each complete double-stroke there is a discharge equivalent to the capacity of the two working barrels.

Mr. J. O. Lundberg, of Bruzaholm, Sweden, has patented several very excellent pumps for small quantities of liquids and fluids, amongst which we find a patent secured by him in Sweden in 1885, a sectional elevation of which is illustrated in Fig. 126, in which A and B are the pump chambers. These two castings are secured to one another by the flanges C and D, by means of bolts and nuts. The upper part A forms the cylinder E and the air-vessel; the bottom part of the cylinder projects into the bottom part of the pump B, through F in it.

To form a tight joint between the cylinder E, which is provided with a flange G and the rough flange F, a packing ring H is introduced. For the same purpose a nipple or bung is formed on the flange C. In the cylinder works a piston J, moved up and down by means of a lever

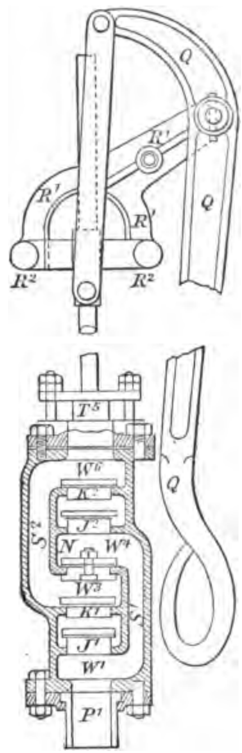
or any other convenient means. The piston J is surrounded by a packing K, which can be tightened by the nut L. The cylinder E is open at the bottom and

FIG. 126.



furnished with projections M M M; these projections serve as stops for the suction-valve P, which latter covers the suction inlet from the suction-pipe U and the space Q. From the top part A, of the pump projects the hollow bracket X, which is used as a fulcrum for the lever V Z, which by means of the link N communicates motion to the piston J. The hollow in the bracket X, increases the capacity of the air-vessel. The delivery-valve is of the annular ring type guided by the pump working-barrel. These pumps are frequently worked by wind power for irrigation and reclaiming land.

FIG. 127.



A neat and compact arrangement of double-acting piston-pump for small sizes is illustrated in Figs. 127, 128, and 129. It was secured by Royal Letters Patent in the year 1886, by Mr. Thomas Ward, of Tipton.

Fig. 127 represents a sectional side elevation; Fig. 128 a side elevation; and Fig. 129 a sectional front elevation.

In the Patent Specification Mr. Ward states:

"I provide two pairs of valves, J_1 K_1 and J_2 K_2 respectively, situated upon a common line of axis, running about parallel with the pump barrel M_1, each pair of which consists of a suction-valve surmounted by a delivery; and which pair are separated the one

from the other, preferably by what would appear to be a fifth valve seat, carrying a plug or false valve N. Immediately below and above, and upon the same axis, the

Fig. 128.

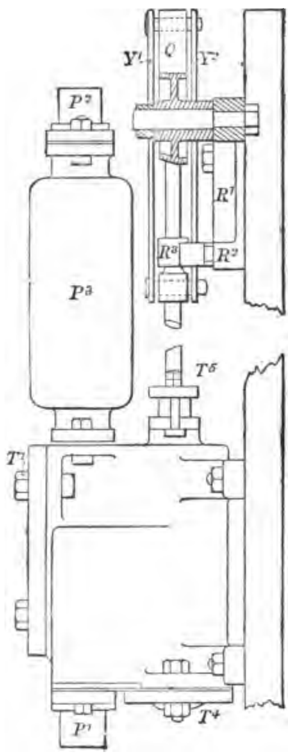
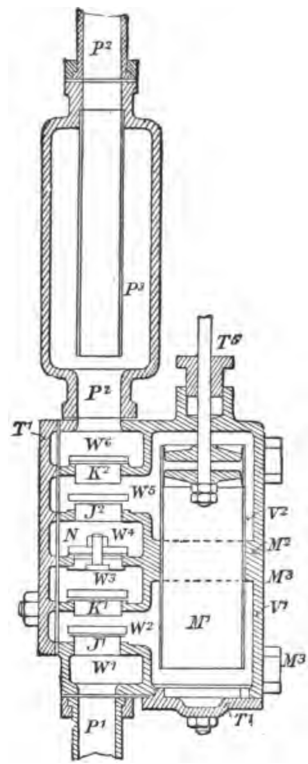


Fig. 129.



suction and delivery pipes P_1 and P_2 are connected respectively, the latter with or without any intermediate air-vessel P_3; thus providing that a boring bar may be

passed right through the lot. Now a port or bye-pass S_1, communicates from the former, with and beneath the suction valves on the one side of the valve-box; whilst a similar one S_2, to the latter; with and above the two delivery valves; and in front a comparatively long and narrow lid T_1 is provided, whereby the valves and the division plug are accessible.

"Again, I may provide a separate working barrel M_1—preferably a plain tube requiring neither boring nor turning—forced and secured within a bored flange M_2 internally projecting from the shell M_3 at about its mid-length, which shell, being of superior diameter, ensures that a pair of annular ports V_1 and V_2 communicate from the pump M_1, above and below the internal flange M_2, to the respective valve chambers W_2 and W_5, situated between the corresponding suction and delivery valves; and I may provide but one cylinder cover T_1, by preference situated at the end opposite to that containing the piston-rod and stuffing-box and gland T_5.

"I may further provide that the fulcrum plate R_1, which carries the lever Q, shall be in one and the same casing as that of the spear-rod-guide R_3, which guide projects forward, and spans between its abutments R_2 R_2, sufficiently to ensure free vibration to a pair of connecting straps Y_1 Y_2, between which it is also situated, sandwich fashion, in its other direction.

"For horizontal pumping, I may provide either a vertical valve box to a horizontal barrel or pump, or else I may provide a horizontal valve-box, whose valves preferably hinge from the cover above, which cover may likewise form the air-vessel communicating with the fluid, either at chamber W_3 or W_6 or other.

"If desired, either or both of the suction and delivery pipes may be connected at S_1, and S_2 respectively, rather

than as provided; and, finally, the pump barrel and annular ports as particularly described may be replaced by other forms."

A method of pumping liquid lead is described in *Engineering*, dated January 1st, 1886, page 18. Although the apparatus used is not a pump, strictly speaking, the author thinks it will be both interesting and perhaps to many readers useful. Here is the article in full: "A steam pump for Liquid Lead. B. Rösing, of Friedrichshütte, Germany, has lately introduced an apparatus for pumping molten lead by steam pressure. Its special use is to facilitate the casting of lead into pigs, or its removal from one pot to another during desilverising, and other operations in cases where the pots are not so placed as to allow of its being simply run out from tapping holes in the pot bottom. The pump consists of an iron cylinder closed at both ends, but provided with a ball valve at the bottom, and having two pipes fixed into the top end, one pipe delivers the steam jet under the cover, and the other, the delivery pipe for the lead, reaches very nearly to the bottom of the cylinder, while outside and above, the cylinder is raised to a suitable height, and is curved over for the convenient flow of the lead.

"If a lead pot is to be emptied, say into pig moulds, the pump is first heated to such a degree that the liquid lead will not congeal on it, and is then sunk into the metal. The steam pipe has on it a three-way cock, which is now connected to the pipe from the boiler. The cock being first turned so that the pump cylinder communicates with the air, the lead outside raises the ball-valve and fills the cylinder. The cock is then turned so that the communication with the air is closed, and steam of suitable pressure is let in. This at once closes the ball-valve and forces the lead to rise in the delivery-pipe. In this way

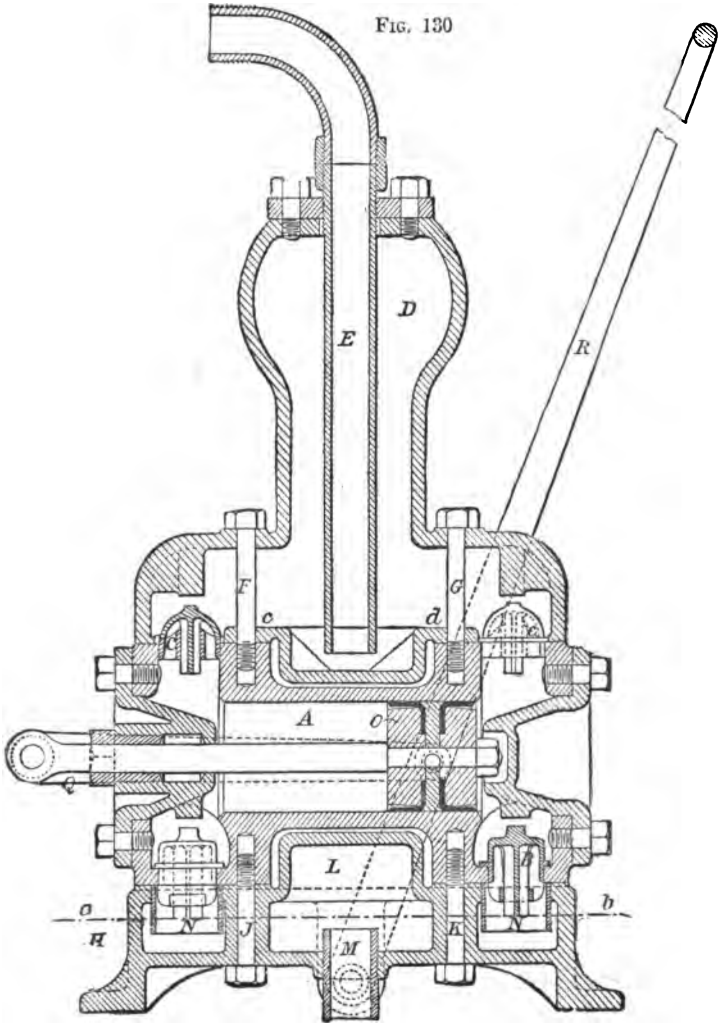
the cylinder is emptied, and as soon as the lower end of the delivery pipe is free from lead, the steam rushes up it, thus lowering the pressure in the cylinder so far that the lead can again open the ball-valve and rise in cylinder. The steam pressure then again rises, closes the ball-valve, and expels the lead as before up the delivery pipe. These alternations follow one another very rapidly, and an almost continuous stream of lead is ejected from the pump, as long as enough remains in the pot to open the valve and rise in the cylinder.

"German metallurgist papers speak of the pump as working" very well indeed at those works which have adopted it, proper relations being maintained as to size of pipes, cylinder, steam pressure, &c. Of course, in principle, this idea is anything but a new one. In sugar refineries, hot liquors have long been raised by exactly similar apparatus, and the "acid eggs" of sulphuric acid works are the same thing, only using compressed air in place of steam, and being made without a self-acting valve for refilling the pump, the liquor to be raised being run in from a pipe with stop-cock for each operation of lifting. The application to molten lead, however, is a new one. The 'New York Engineering and Mining Journal' gives a description of the pump, which it appears to regard as new in principle, as it says "that *it is believed that this apparatus could be used for other hot liquids and (compressed air being substituted for steam) also for cold ones*;" apparently communicated direct from the adopter. From the same source it probably has received the very amusing information which it gives as to the action of the German Patent Office, concerning Rösing's application for a patent for the pump: "It does not appear that any objection was raised on the score of novelty, but the wiseacres at the Patent Office refused a patent because they discovered a

reason satisfactory to their own minds why the pump would not answer. They wrote to the applicant the following piece of wisdon, which, as the 'Engineering and Mining Journal' says, "is *awe-inspiring:—'You have not touched the point most important to the operability of the apparatus, namely, the excessively high pressure, corresponding to the temperature of the molten lead, which the steam must acquire through contact with it, and which renders doubtful the operability and applicability of the apparatus.'* As our contemporary points out, the supposition that excessive pressure could be produced by superheating one end of a small steam current which is in open connection with the boiler, is, of course, perfectly absurd, and astonishing for the Patent Office of a country where science *lies around loose for everybody's benefit.* When this solemn suggestion was put forth, this pump was working perfectly. But the patent has never been granted, and it appears that the officials concerned are quite sure the apparatus will not work."

In the year 1887 we find that Mr. Johan Olof Lundbergs, through Mr. William Phillips Thompson, secured a patent for "Improvements in double-acting piston pumps." One of these pumps is illustrated in Fig. 130, which is a sectional elevation. A is the working barrel, at the ends of which the valves B and C are placed. The air-chamber or vessel D, with the dip pipe or rising main E fitted therein, is secured to the cylinder by means of set screws F, G. Into the base H, also secured to the cylinder by means of the set screws J, K, there extends beneath the valves B a compartment L, into which the suction-pipe M enters a short distance. Under the valves B are short lengths of pipes N, descending into the compartment L. As the piston O advances and returns in the working barrel, the water is sucked through the pipe

Fig. 130



M into the compartment L, and from this compartment, through the pipe N and the valves B, into the working barrel A. The water is then forced up through the valves C into the air-vessel D, whence it is forced up into the rising main E. In consequence of the rarefaction of the air produced in the compartment L, which thus acts as a suction air-vessel or vacuum-vessel, the water is sucked in a continuous stream from the pipe M. By reason of the suction-pipe M extending some distance above the bottom of the suction air-chamber L, the water level in the said chamber will, when the pumping is discontinued, subside to the line *a b*. In the air-chamber D the water will subside to the line *c*—*d*. This arrangement has the advantage that, when the pumping recommences, the plunger will immediately aspire the water in the chamber L, which water serves to tighten the packing of the piston and the surface of contact of the valve seats, and at the same time it prevents the air from being aspired through the pipe E, in the event of the valves C not being perfectly tight. The suction-valves B have their guide below the valve seats, in order that the inlet area may not be reduced, the guidance of the valve being besides more certain. The delivery valves C are, like the previous ones, guided inside, in order to occupy the least possible space. The piston is worked by means of the shaped lever R, pivoted at the base of the pump, and by means of a bent link Q, which is connected with the piston rod.

Another arrangement of Mr. Lundberg's small double-acting piston pumps is shown in Figs. 131 and 132, in which all the valves are placed above the working barrel. The suction air-chamber consists of a pipe R, the lower end of which is screwed fast in the body of the pump, and over this pipe is passed the delivery air-chamber S, which

is, moreover, united with the pipe R by means of box-coupling T. By this arrangement the suction air-chamber is placed in the delivery air-chamber, and the lower part of the latter, which constitutes the lid of the delivery

FIG. 132.

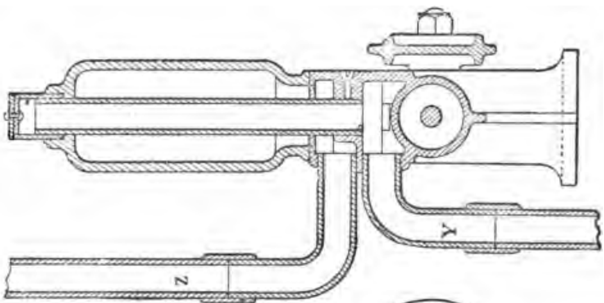
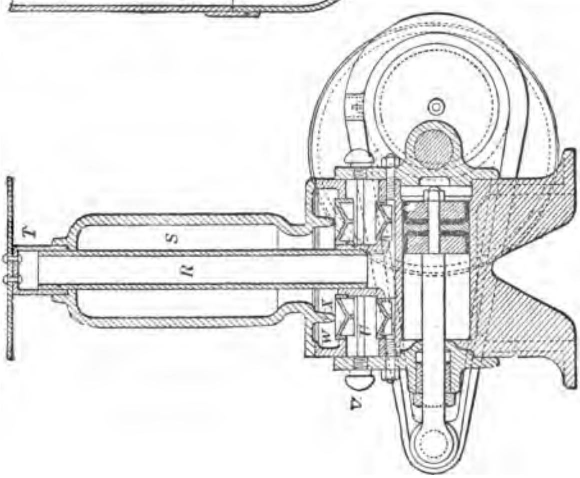


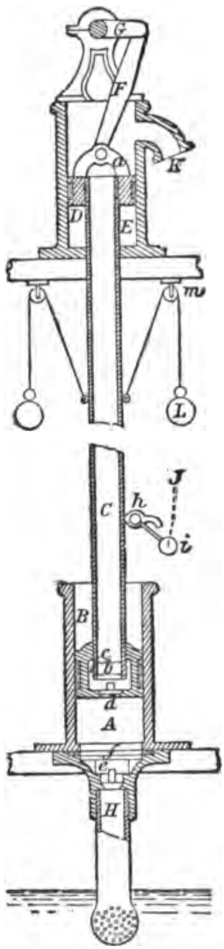
FIG. 131.



valve box, is pressed, by means of the box-coupling T, against the upper surface of the pump body, by which means, if packing is laid between the two surfaces, a tight joint may be produced. The lift of the suction-valves U

is determined by the screws V, introduced through the cylinder covers, whilst the delivery valves W come in contact with the shoulders X projecting downwards from the air-chamber. The water passes through the suction-pipe Y into the compartment beneath the suction-valves. When the piston is pushed forwards, the water rises through one of the suction-valves, and passes through a port at the end of the cylinder into the latter, and is then forced through the port and the delivery valves to the delivery air-chamber and off through the delivery pipe Z. By removing the air-chamber, free access to all the valves may be obtained.

Fig. 133.



The usual manner in working deep-well pumps is by means of the ordinary well rods or spears, but Mr. Valentine Morris, of Ipswich, has secured a patent by means of which he uses a hollow rod, which he also uses as the delivery pipe or rising main for the pump; this patent is dated January 15th, 1887. One of his arrangements is shown in Fig. 133. In the specification he states:—"In carrying out the improvements according to my invention, I employ a barrel, or barrels, A, of metal or other suitable material, in which a bucket

B may work freely, said bucket being packed to allow of its fitting the bore of the barrel, A, so as to be air-tight, and thus prevent the leakage of water or other fluid during the operation of pumping.

"A vertical reciprocating motion is imparted to the bucket, B, by means of a hollow rod, C, which passes upward to the top of the well, pit, mine, or other place from which it is desired to raise water or other fluid. To the upper end of the hollow rod, C, which is provided with a flange, is attached, by screwing or equivalent means, a piston, D, open at the top, which works freely in a guide-barrel, E, or the hollow rod C may be so attached that it passes through said piston, as shown at D; in either case to allow of the water to flow freely.

"A bridge *a* is formed upon the piston D, so that an ordinary connecting rod F may be jointed, by means of which motion is imparted to the piston D, hollow-rod C, and bucket B, said motion being derived from manual power, through the medium of cranks and gearing, a simple crank, or a lever, which may or may not be weighted.

"Steam or other sources of power may, however, be utilised for driving any pumps according to my invention, through the intervention of the usual wheels, barrels, levers, cams, or the like.

"The bucket B, within the working barrel of the pump A, is chambered, and the hollow rod C is formed with a closed end *b* passing through the top of the bucket into the chambered interior, holes or slots *c* being cut around the sides, to allow of the free passage of water or other fluid into the hollow rod *c*. A suitable valve *d*, with its proper seating, is fitted to the lower part of the interior of the bucket, the said valve opening inwards, and closing when subjected to internal pressure. The base of the barrel A is fitted with a similar valve *e*, serving the

purpose of a foot valve, and opening and closing the orifice of the upper end of the suction-pipe H.

"The valves *d* and *e* may be of any suitable form or material, but I prefer to use ordinary conical valves; the foot valve *e* having a perforated guard plate *f*, recessed into the flange of the suction-pipe H. In certain cases I may dispense with the foot-valve altogether, the barrel A being submerged below the level of the water or other fluid that is required to be raised, the water or other fluid flowing into the working barrel A through slots or orifices. The arrangements above described may be applied to any of the forms of pumps according to my invention, to suit special requirements.

"In order to clear the hollow rod C of water or other fluid after working, or of air during the first stroke of the pump, I provide a cock *h* with a weighted lever *i*, which keeps it closed when tension is not applied to the cord, chain, or rod *j*.

"In working pumps constructed according to my invention, on power being applied to the crank G, or lever, or other medium of transmitting reciprocal movement, the guide piston D, carrying the hollow rod C, is caused to move up and down within the guide-barrel E. The working piston or bucket B, is also moved up and down within the barrel A, by means of its attachment to the hollow rod C. This displacement of the bucket during the upward movement, allows of a partial vacuum being created below it in the barrel A, which causes the water or other fluid to flow upward through the suction-pipe H, opening the foot-valve *e*, by reason of the reduced pressure upon the upper surface. The barrel having become partially filled during the up-stroke, at the commencement of the down-stroke a pressure is created below the piston or bucket, which closes the valve *e*, and

opens the valve *d*, affording ingress to the water or other fluid into the interior of the hollow rod C. This operation being repeated by continuous strokes of the bucket, the rod C becomes filled and a column of fluid supported therein, the added increment of which during each successive stroke flows from the open top of the hollow rod C, above the guide-piston D, and is conducted away by the pipe or by a spout K.

"It is obvious, therefore, that the act of raising a column of water or other fluid within a hollow rod C, does not require mechanically the exertion of any greater degree of force than if such column of water or other fluid were maintained within a long suction-pipe or stationary discharge-pipe, as in the case of pumps as hitherto ordinarily constructed; but the greater weight of a long hollow rod may in certain cases require a counter-balance, which is provided for by reason of the descent of one rod and bucket neutralising the weight of the opposite ascending rod and bucket of equal weight. In other cases I may employ counterweight L, with chains or cords passing over suitable pulleys *m*."

Now we come to two pumps, improvements upon Bramah's pump, page 25, patented in England in the year 1887, by Mr. J. O. Lundberg, of Sweden. The patentee has given them the name "Flap-valve Pumps." The first relates partly to a flap-valve pump provided with a suction air-chamber surrounding the barrel of the pump. This pump is illustrated in Figs. 134 and 135. It is arranged as follows:—The valve-box or cylinder A, of the pump has, as usual, a lid, B, through which passes the shaft C, on which the flap-valve D is secured. The walls of the cylinder A are hollow all round, and the space E thus obtained is connected below with the suction-pipe F, and serves as a

suction-chamber. The circular space E communicates likewise with the interior of the pump by the ports G (Fig. 134), these ports being opened and closed by means

Fig. 135.

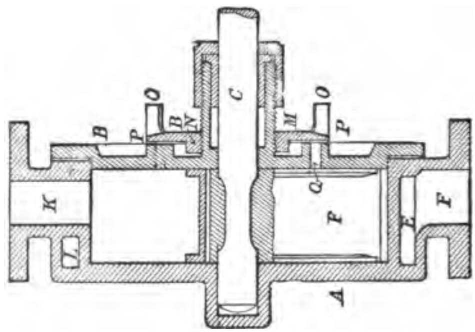
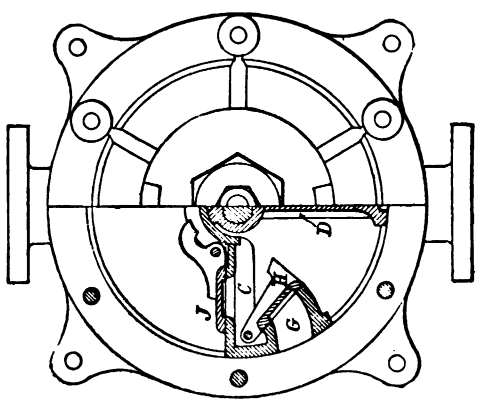


Fig. 134.



of the suction-valve H on both sides of the pivoted valve D. The top valve J, as usual, placed immediately above the suction-valves, and the arrangement of the flap-valve and the other valves does not materially differ from that

of a common flap-valve pump. The top of the interior of the barrel communicates with the delivery pipe K. The space E, however, is not partitioned thereby, for, as shown in Fig. 135, behind the enlargement on to which the pipe K is secured, the space is narrowed to a passage L, thus effecting the communication between the two halves of the space E. The space E can, however, be divided into two parts by filling up the passage L, when two suction chambers are obtained, one for each valve. The lid B is, as usual, secured fast to the cylinder, packing being laid between the surfaces of contact. In the centre of the lid is a stuffing-box M, through which the shaft C of the flap-valve passes. On the box M, and provided with a screw-thread, there is a disc N, having wings O, by which it may be turned round. The underside of the disc N, when screwed down, rests, with the intervention of packing, against a ring P on the front of the lid. Holes are so arranged in the lid that one or more of them Q″ and Q‴ extend to the space under the delivery valve J, and one or more of them Q′ to the space above the said valves, When the disc N is screwed outwards from the lid, the outer ends of the holes Q′, Q″, and Q‴ will be uncovered, whereby the water in the pump is partly enabled to get out, and the air partly enabled to get in. In order to effect a complete exhaustion of the pump, the flap-valve D should be moved to and fro by means of a lever on the shaft C of the valve, which will facilitate the exit of the water on either side of the valve. The air thus enters through the small holes Q″, and the water flows out through the holes Q′ and Q‴. By this complete exhaustion the pump will be frost-proof.

The suction chamber of the pump works in the following manner:—When the pumping begins, there is air in the space E, constructed in the walls of the pump

cylinder. Part of this air goes up through the suction-valves H by the alternate motion of the flap-valve, and the water is drawn in through the suction-pipe F. When the water has risen up to the ports it is drawn into the flap valve-box, while the top of the space E fills more and more with water.

Every time the flap valve is moved towards either side, the water is drawn in through the suction-pipe, but when it returns in the opposite direction, the water continues to ascend through the suction-pipe, in order to fill the remainder of the space or chamber E. When the flap-valve has returned, and one of the suction-valves is opened, the pump acts, on the contrary, by suction on the water in the pipe. Thus it is clear that there will occur no shocks in the suction-pipe, but that a suction exists and acts even in the turning movement of the flap-valve, and it will be seen that a pump arranged in this manner yields more water than a flap-valve pump of the ordinary construction, and besides this the suction-pipe may be of a smaller diameter, because the water circulates therein without interruption.

The pump represented in Figs. 136 and 137, is principally intended for walled-in ground; and for driving it, a wind motor may be advantageously employed. The figures are respectively an elevation and vertical section.

A is the pump cylinder, to the end of which the collection chamber, B, is secured, and from which the delivery pipe, C, ascends. The pump has eight valves in all, namely, four in each end of the cylinder. The valves F, G, H and J, in the end D, are provided with strengthening flanges, and are placed on the inner side of the cylinder end, so that they may open inwards to the pump, and they thus become suction-valves. The valves L, M, N, and O in the cylinder end K, which are opposite the

suction-valves and open towards the interior space B, are, on the contrary, placed on the outer side of the said end K, so that they open into the space B, and thus they con-

FIG. 137.

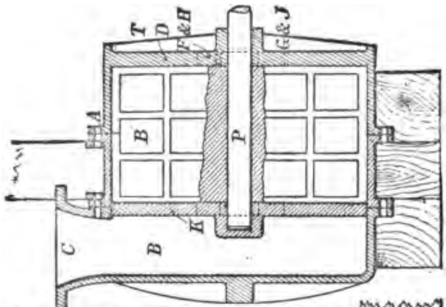
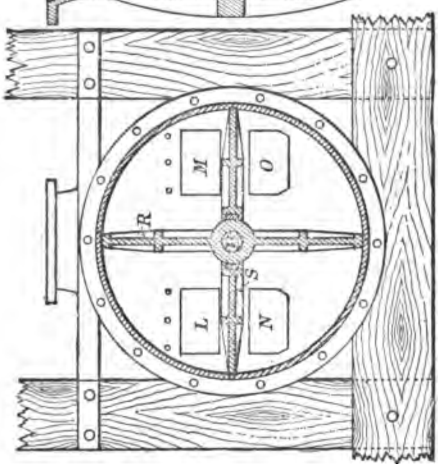


FIG. 136.



stitute tl e delivery valves. On the shaft P, which passes through the pump cylinder, the flap valve R is fixed. In addition to the flap-valve R, the interior of the cylinder is divided into two equal parts by the fixed partition wall S,

which fits into a groove in the ends and in the sides of the cylinder, and extends close up to the centre of the flap-valve. When the flap-valve is moving in either direction, water enters the cylinder through two suction-valves, and is at the same time forced from the cylinder into the space B through two delivery valves. When the flap-valve returns in the opposite direction, the water enters into and is forced from the pump by the two suction and delivery valves situated diagonally opposite to the valves just named. By imparting an oscillating motion to the flap-valve, the pump will thus have a quadruple action as compared with a single-acting pump with only one suction and one delivery valve. A metallic wire gauze, T, fastened on a projecting flange on the cylinder, and on the centre of the cylinder end D, surrounds the shaft P, and prevents any solid matter from getting into the pump.

REMARKS ON DESIGNING PUMPS, PRACTICALLY AND THEORETICALLY.

It is rather difficult to determine where the practical and the theoretical parts in the construction of pumps commence and terminate; they are so woven together, one cannot exist without the other.

After these few remarks, the Author will proceed with pointing out the most prominent features to be noted in designing a pump.

All valves and ports should be arranged so as to obviate the possibility of *air lodging* at any part. The air always rises to the highest point.

The various sections of the pump should always have, as near as possible, the same area, for the reason that when the area increases or decreases, the speed of the water is likewise affected; consequently a shock occurs when currents of water with different speeds meet. This cannot conveniently be carried out with horizontal pumps, therefore, the ports and passages should be kept the same area as the clear area of the seats of the respective valves.

The area of the valve box should be equal to the area of the top of the valve plus the area of the valve opening; that is to say, the annular space round the valve should be of the same area as the clear area of the valve opening.

All bends should have an easy curve. They are in Germany mostly made one-half of an inch larger in

diameter than the straight passages, to compensate for the additional friction in the bends.

All passages should be made round, because they create less friction and are stronger.

Sharp corners should always be avoided, except where the current of water is desired to be spilt, as in centrifugal pumps with suction admission at each side of the casing.

The top of the suction-valve box should never be above the top of the pump barrel.

The under side of the delivery valve seat should be level with, or above, the top of the pump barrel.

The water should never be allowed to meet a flat surface.

The plunger should not be flat at the end, as usually made in England, but made in the shape of a parabola or an ellipse.

The clearance space should be made as small as possible. The distance between the two valves and the piston or plunger, as the case may be, should be little; otherwise the suction power of the pump will be greatly reduced.

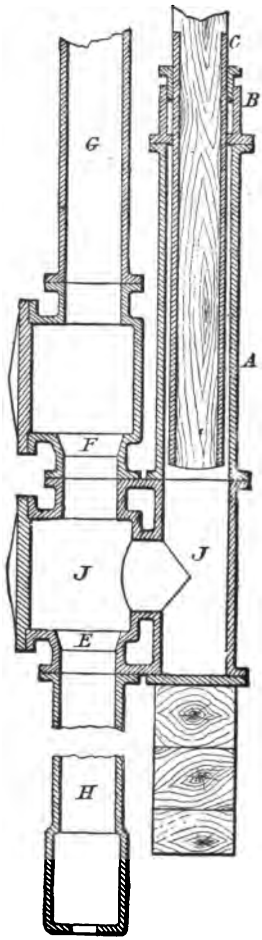
Covers, for access to the various valves, buckets, pistons, and plungers, should always be provided, for easy access for repairs or cleaning.

In vertical pumps, especially when of a large diameter, the suction pipe should be of the same diameter as the pump barrel, or ram pumps the same diameter as the ram, and the delivery pipe not less than half the area of the barrel. The larger the pipes the less friction, consequently less power is required to raise a certain quantity of water to a given height.

The working barrels or pump "trees" (so called because originally they were made from logs of trees) are mostly formed of cast iron; wrought-iron pumps are

rarely used, except for mountainous countries, where they are to be carried by horses or mules, in short pieces for facility of transit, and ultimately put together at the mines. In some of the Mexican mines cast-steel pumps were introduced to save expense of carriage, but, not proving a success, were replaced by ordinary cast-iron pumps. When the water is very corrosive, the pump barrels for ram pumps, and also the H-piece, or suction valve-box, J, Fig. 138, in which the suction valve, E, is fixed, are lined with narrow slips of wood.

FIG. 138.



The tendency of the cylinder or working barrel to become oxidised when iron is used as the material of construction, often constitutes a serious difficulty, especially in cases where the water is charged with substances capable of determining rapid oxidation. In pumps for draining mines the working barrels and buckets, when made of iron, are frequently destroyed in a short time, and of course, in such circumstances, a satisfactory degree of efficiency is not to be looked for. To remedy this defect the cylinders are sometimes lined with brass, and

though the first cost is considerably enhanced thereby, the additional outlay is soon recovered in the higher efficiency of the pump, while the greater durability of the working barrel renders such outlay a real source of economy.

The pumps for direct-acting steam-pumps should be made as light as possible, consistent with strength, to reduce the carriage and custom-house duty to a minimum, the latter being in some countries charged by weight.

The principal thing to look at, from a practical point of view, is the machine work; all, as far as possible, should be done in a lathe or milling machine, so as to leave as little work as possible for the fitter.

No studs should be used wherever a bolt can be put in, as much annoyance, loss of time, and often a great loss of money, is caused by a stud breaking, as the old stud generally must be drilled out before a new one can be put in; bolts are also cheaper. This is most important in mine pumps.

All work that can be done should be done by piecework, carefully examined by an impartial and competent foreman, especially the studding of a pump. The Author had once great experience with this, and found, in many cases, studs put in only two or three threads deep. This can easily be detected when studs are screwed at each end only, but when the studs are made from bars screwed all the way and cut off to lengths when wanted, the workmen must be carefully watched.

All facings should be on as few sides as possible, so as to have few settings of the pump on the machine, except when machines are at hand where two or more sides can be faced at once.

As regards boring, it is cheaper to have a cover at each

end, for then the cutters in the boring head can be set to different diameters, and the pump bored by the head passing through it only once.

Uniformity of metal all through the pump, to equalise the contraction in cooling, when cast, should be considered.

The valve seats should be above one another; the suction valves central with the delivery valve, so that they can be bored out at the same setting.

The cheapest plan is to make the delivery valve and seat so much larger than the suction valve and seat that it may drop through the former, because one top cover will do for both sets of valves. This plan is also more convenient, as there is a quick access to both valves in case of examination or repairs.

One suction and one delivery valve for each end of a double-acting piston-pump is the cheapest and best for the action of the pump, as it prevents eddies, and if the valve is properly constructed, guides the flow of water in the proper direction.

Deep-well pump barrels should be placed as near the surface of the water in the well as possible; and in cases where the pumps are likely to be flooded, the pump trees should reach above the highest water level, and buckets and valves arranged to be drawn out from the top.

When hot liquids have to be raised, the suction should be as low as possible, in fact it is best to have the water running into the pump, that is, having the tank or cistern from which the pump gets its supply placed above the level of the pump barrel.

The main features of centrifugal pumps are the vanes or blades. The present well-known shapes are the results of numerous experiments. The idea was at first to *drive* the water by means of the blades, and the blades were

made *straight and radial.* The results were most unsatisfactory. A *straight blade placed at an angle* was next considered, and, upon experiments, proved greatly superior to the straight and radial vanes. The *curved vanes* were next experimented with, with good results; for whereas the duty attained by straight radial vanes was only 24 per cent., with straight vanes placed at an angle of 45 degrees 43 per cent. was attained, which was increased to 65 per cent. by means of curve vanes.

From this it appears very clearly that by *leading* the fluid, an amount of duty is obtained greatly beyond what driving would ever attain. The point to consider is therefore the form of vanes best suitable for the purpose.

The shape of the vanes should be arranged to facilitate the flow of water, and to leave the impeller without shock.

Mr. David Thompson, in a paper on Centrifugal Pumps, read by him before the Institution of Civil Engineers, said:—"It would appear that the general contour of the arm may be varied without any material deduction from the duty, but the angle which the arm subtends being fixed does not admit of much doubt what curvature to give them."

Some makers form the arms or vanes straight two-thirds of their length, then curve them towards the periphery in an opposite direction to the line of rotation for low and moderate lifts, and with the line of rotation for high lifts.

The circumferential end of the vanes should finish at an angle of about 20 degrees to the tangent.

The vanes are generally six in number, and subtend one-third to one-fourth the circumference of the impeller.

The vanes should be made as thin as possible, to avoid obstruction to the entering water, thereby preventing the

stream from becoming broken and agitated in its passage through the impeller.

The passages through the impeller should be so proportioned as to gradually increase the velocity of the water until it arrives at the circumference, when a gradually decreased velocity should take place until it enters into the delivery pipe.

The clear width of each division between the side plates of the impeller and the centre plate should be equal to one-eighth the diameter of the impeller; if there is no centre plate, the distance between the cheeks should be one-fourth the diameter of the impeller at the centre opening. The impeller should have its least width at the periphery, and become gradually broader until its edges intersect the opening in the centre through which the water is drawn.

Mr. David Thompson remarks that the contraction of space at the sides of the fan, to give uniform opening through the fan, has been tested, and no increase of duty given. Looking at it theoretically, it would appear to be more correct to enlarge the area of the fan towards the circumference before its discharge, and thus be made to part with a portion of its *vis viva.*

When no centre plate is used, there should be a central disc, secured to or cast in one with the centre boss, a little larger in diameter than the inlet to the centre of the impeller, and the circumference of this disc should be brought down to a knife edge.

All changes in the direction of the flow of the water should be gradual.

All corners should be well rounded, and all curves should be as easy as possible.

All expansions and contractions in passages should be made gradually.

The case is sometimes made in the shape of an helix, commencing at the top and gradually increasing until it reaches the delivery pipe.

The delivery or discharge pipe should be placed tangentially with the casing, to guide the flow of the water into it.

The vertical height of suction should be made very little, in fact it is best to have the water running into the pump. The greatest depth from which ordinary centrifugal pumps can draw water is 25 feet, but in practice it should never exceed 15 feet.

At the point in the suction pipe where it branches off to the sides of the casing, the passage should be formed into a knife edge, to cause as little obstruction as possible to the flow of water.

At the highest point of the casing a cock or valve should be provided for letting out the accumulated air, or a connection by means of a small hole or passage between that point and the rising main.

An arrangement should be provided on the top of the casing for charging the pump and suction-pipe with water before starting.

A cock should also be provided at the bottom of the casing, for emptying the water out of it in frosty weather when the pump is stopped.

CLASSIFICATION OF PUMPS.

The term "*pump*" implies a machine for raising water or other liquids or fluids by means of the atmospheric pressure.

Force may be applied to a liquid through the medium of a pump in two modes; one being to bring the liquid *upon* a piston, working up and down in a cylinder, to the upper end of which a pipe may be fixed; the upward motion of the piston then raises the water at every successive stroke until it eventually reaches the top of the cylinder or pipe. Pumps of this kind are called "lift pumps," because the liquid is lifted up by the piston or bucket to the required height. It is obvious that this height is limited only by the strength of the materials and the force available. In such a case atmospheric pressure is employed to raise the water a portion of the height. The part of the pump which is below the bucket is called the "suction," and that above it the "lift."

Another mode of applying force to the fluid by means of a pump is to bring the fluid *beneath* a piston working up and down inside a cylinder, the downward movement or stroke of the piston forcing the fluid up through a pipe provided, or in any other direction that may be required. A pump of this description is called a "force pump," and possesses many advantages over the preceding one, which will be explained under the proper head.

There is a third general division of pumps, combining the two classes, and called "lift and force pumps."

Lift pumps are represented by the ordinary bucket pump, Fig. 139.

The force pumps are represented by the ram or plunger pump, Fig. 138, page 177.

The lift and force pumps are represented by the piston and plunger pump, Fig. 140.

FIG. 139.

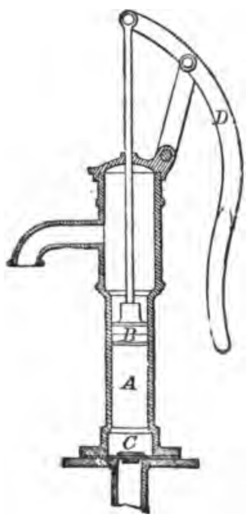
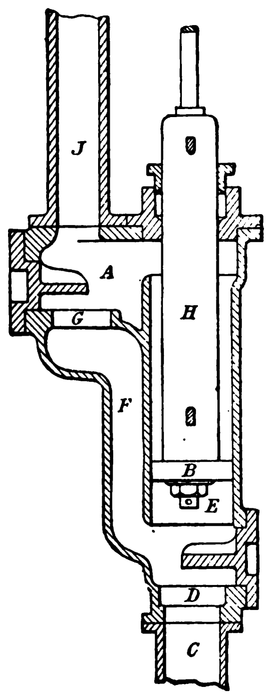


FIG. 140.



ACTION OF DIFFERENT TYPES OF PUMPS.

SINGLE-ACTING BUCKET PUMPS.

A pump in its simplest form, Fig. 139, consists of a working barrel, A, into which fits a bucket, B. This bucket is fitted with a valve which opens upwards; a valve, C, is also fitted at the bottom of the barrel, which likewise opens upwards. This latter valve is called the "suction" valve, or, perhaps, more commonly, the "sucker."

Now, if the bucket B is raised in the barrel A, by means of the handle D, or other mechanical arrangement, a partial vacuum is formed under it, more or less complete according to the perfection of the working parts and tightness of the suction pipe. The valve in the bucket is kept shut by the pressure of air above it, while the suction valve C will be forced open by the water rising into the barrel, the water being forced into the space otherwise forming a vacuum under the bucket B, by the atmospheric pressure on the exposed surface of the water in the well; in other words, by abstracting the pressure of air from part of the surface of the water, that portion of water under the bucket is forced upwards by the pressure on the remaining portion of its surface. Supposing the up-stroke of the bucket completed, and the space under the bucket filled with water; on commencing the down-stroke the water cannot return through the suction-valve C, for it shuts immediately by the weight of the water, but the bucket valve will open by the same

effect. Thus the water will be forced from the underside to the top side of the bucket. It will be easily understood that the water above the bucket can be lifted to any height required; but the height to which the water under the bucket can be raised above the natural level of the water in the well is limited by the law of nature within the range of 30 feet to 32 feet; that is, if the vacuum could be obtained perfect, there could not be more than 30 feet to 32 feet from the surface of the water in the well to the top side of the bucket when it is at the highest point of its stroke. A comparison of the relative weights of water and air would appear to warrant us placing the suction valve of a pump at a greater height above the surface of the water in the well or pit than is usually adopted in practice, but the imperfection of different parts of the pump do not admit of it being carried beyond 20 feet to 25 feet; the Author, however, prefers two pipes each 9 feet long, or 18 feet from the level of the water in the well to the suction valve, except when the stroke of the pump is very long.

Continuous Flow Bucket Pump.

Fig. 102. Supposing the buckets to be moving towards the left, the centre bucket will suck in the liquid; at the return stroke, the water in front of the bucket D passes through it. The three working barrels having thus been filled, it will be clearly seen that when the buckets go from right to left, the bucket D is sucking, and delivering the liquid to the buckets E and F, and that the water is compelled to pass through those buckets; at the return stroke the suction water passes through the bucket D, and the buckets E and F force the liquid through the delivery pipe.

Single-acting Piston or Ram Pump.

Fig. 138. The action of this pump is as follows:—When the piston or plunger is raised, the water enters the barrel A by means of the suction pipe H and the suction valve E, the delivery valve F being held down by the pressure of the column of water in the delivery pipe G; on the return stroke, when the plunger is allowed to go down, the suction valve E closes immediately and the water in the barrel A is forced through the delivery valve F into the rising main G.

Hollow Ram or Plunger Pump.

Fig. 16. The action of this pump is thus:—At the up-stroke of the plunger the water enters through the suction valve and fills the space under the plunger; on the down-stroke the water passes through the plunger and the delivery valve; therefore it has this great superiority over the plunger pump—the water rises in the direction it enters the barrel, and is not met by a flat, solid plunger, reversing its flow, which reversal causes a shock, increases friction, and consequently a diminution of the useful effect of the machine.

Bucket and Plunger Pump.

Fig. 8. Its action is such that when the bucket B is raised it sucks a column of water equal to its area, its length being the same as the length of the stroke; at the return stroke, when the bucket is travelling downwards, the water passes through the valve in the bucket to the upper part. The ram or plunger C, being one-half the area of the bucket B, leaves an annular space round the ram equal to half the area of the entire space of

the suction side, therefore it will be found that half the quantity of the water is raised into the rising main N, through the delivery valve L, the other half portion remaining in the working barrel above the bucket; when the bucket again moves upwards, the remaining half of the water is then lifted into the delivery pipe N. From this it will be seen that half the quantity is delivered at the up, and half at the down stroke; consequently the pump is double acting, but delivers only the same quantity as a single-acting pump of the same area as the bucket, or as a double-acting pump of the same area as the ram.

Piston and Plunger Pump.

Fig. 140. The action of this pump and the Bucket and Plunger type is very similar, as will be seen from the following:—The piston B is raised and the water sucked through the suction pipe C and the suction valve D into the working barrel E; on the return stroke, when the piston travels downwards, the water is forced from the barrel up the delivery passage F, through the delivery valve G. Now the area of the ram, as in the former case, is only one-half the area of the barrel; the annular space round the ram H is also one-half the area of the working-barrel; one-half of the water sucked at the up-stroke fills the annular space above the piston, and the other half is forced up the delivery pipe J; when the piston again moves upwards, the remaining half of the water is lifted into the delivery pipe J.

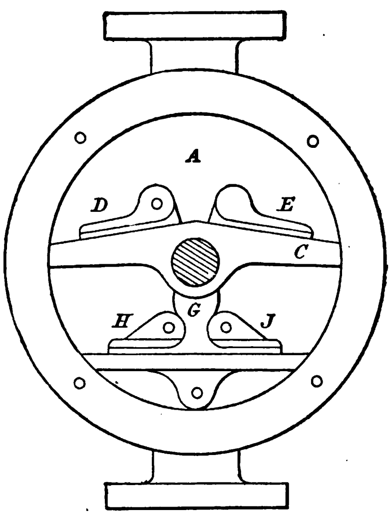
Continuous Flow Bucket and Plunger Pump.

Fig. 13. The action of this combination of pump will be clearly understood when we consider separately the action of each class of pump. If the bucket B and the

plunger P are raised together, both will suck and fill the working barrels with the liquid they are raising; now when they descend, P forces the liquid through the bucket B.; the water which was in the bucket barrel will also pass through the bucket; therefore the water out of one barrel will be forced into the rising main and the other barrel above the bucket; on the next up-stroke the water in it will be lifted into the rising main. From this it will be seen that the water is continually flowing up through the delivery pipe, hence the pump is called continuous or continually flowing pump.

Oscillating or Flap-Valve Pump.

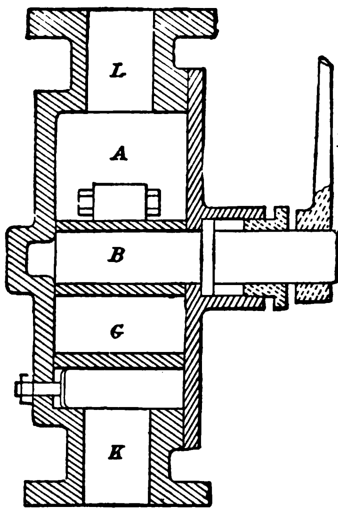
Fig. 141.



Figs. 141 and 142. The action of this pump is as follows:—When the lever is moved towards the left, the

suction valve J will open and fill the right-hand side of the cylinder, and the valve D will open and deliver the

FIG. 142.



water out of the left-hand side of the cylinder. Now if we move the lever towards the right, the suction valve H will open and the left-hand side will be filled, the valve E will open and deliver the water from the right-hand side.

Centrifugal Pumps.

Their action may be described thus:—The pump being charged with water, the impeller or fan is set in motion at a great speed, imparting centrifugal motion to the water contained in the impeller, and so driven into the casing or body of the pump; by the partial vacuum thus created

in the impeller the water is forced up the suction pipe by the pressure of the atmosphere; the water entering the disc receives again a centrifugal motion, and by this means a continuous stream is received into and discharged from the pump. This fundamental principle applies to all centrifugal pumps.

ADVANTAGES AND DISADVANTAGES OF DIFFERENT TYPES OF PUMPS.

Bucket Pumps.

The advantages of the bucket pump are: the bucket fitting the working barrel, there is less body of water between the bucket and the suction and delivery or bucket valves; therefore a more perfect vacuum can be obtained, and the working barrel is more certain to be filled.

The "wet spear" bucket pump takes up less room in the pit shaft or well.

The occurrence of air getting into the pump, does not cause the shock which is experienced with the ordinary plunger pump, as the air cannot lodge, but rises straight up.

The disadvantages of the bucket pump are as follows:— The friction of the bucket against the sides of the working-barrel is very great.

The wear of the leathers round the bucket, which make it work water-tight in the barrel, is often rapid, particularly when aided by the action of water charged with sandy and gritty particles, or contaminated by mineral solutions which impart a corrosive action. There is no certainty as to the length of time leatherings will last; it may be three months or it may be three days. In some collieries it is one man's duty to see that there is always a reserve bucket ready to be put in, and the bucket

changed every day. The expense of changing the bucket in a "wet spear" pump is very great, because the rods have to be lifted to the top, ofttimes a great height. In some pumps there is a door called "the bucket door," fitted above the working barrel, then, though the spears have only to be lifted a little, still the spears have to be released and raised. In the "dry spear" pumps, it is only neccessary to knock off the bottom joint of the rods, and the rod and bucket can be drawn and a fresh rod and bucket put in its place in a comparatively short time.

The area of the water-way through the bucket is contracted, therefore causing a great amount of friction.

If any leakage should take place between the bucket and the barrel, it cannot be detected, and may, therefore, continue a considerable time before it is remedied.

Ram Pumps.

The advantages are:—There is less friction in the ram working through a stuffing-box, than in the bucket against the inside of the pump barrel.

When the water—generally the case in collieries and mines—is impregnated with sand, grit, mud, and other foreign matter, the wear and tear of the plunger in horizontal ram pumps is prevented by the space underneath it forming a receptacle for the solid matter, which is not the case in the bucket and piston pumps. A cock should be provided on the underside of the barrel, that the sand or sludge can be blown off at intervals when necessary.

The cost of repacking the ram or plunger is only nominal, but the cup-leathers or other leathering for the pistons and buckets are a great expense.

The ram being packed from the outside, leaks are immediately detected, and the glands can be tightened in a

minute, while the pump is running, and the stuffing-box repacked in a very short time; whereas, in a piston pump, a leak can be going on for a long time without being noticed.

The ram can be lubricated, and the corroding action of of acidulated water greatly reduced.

The disadvantages are:—The great body of water between the suction and delivery valves, consequently less perfect vacuum.

When the valves are placed at the bottom of the working barrel, there is a large space for an air-lodge, and the reversal of the current of water is very objectionable.

When the delivery clack is fixed at the top of the plunger case the air-lodge is dispensed with, and the direction of the current of water is not changed.

With the inwardly-packed ram pumps, as the Worthington, Fig. 41, and the hollow ram pumps, Fig. 16, there is the same objection as with the bucket and piston pumps, namely, a leakage can take place for a considerable time without being detected, especially when working against heavy pressures.

Hollow Ram Pumps.

The advantages of the hollow ram pump are:—That the water passing straight up, the concussion is greatly diminished.

There is not so bad air-lodge as in the ordinary ram pumps.

When the valve is placed at the bottom of the ram or plunger, there is only a little more clearance space than in the bucket pumps; therefore, it has a good suction power.

The disadvantages are:—The contracted waterway through the delivery valve, as compared with the ordinary plunger pump.

The large clearance space when the valve is placed at the top of the plunger, as shown in Fig. 16.

Bucket and Plunger Pumps.

The advantages are as follows:—The pump is double-acting with only two valves, namely, one suction and one delivery.

The pump being double-acting in its delivery, it delivers a more constant stream than the ordinary single-acting bucket pump.

The disadvantages are:—The small area of waterway through the bucket, which increases the friction.

The friction of the working parts is increased by having both a bucket and a plunger.

Increased friction of the water in the suction pipe, on account of the pump only sucking once in one revolution or double stroke, which makes the speed of the water in the suction-pipe double that of an ordinary single-acting pump of the same diameter as the ram. The remedy for this is to make the suction-pipe twice the area of the pipe for single-acting bucket or plunger pumps.

Piston and Plunger Pumps.

The advantage of this pump over the bucket and plunger pump is a large delivery passage, instead of the throttled waterway through the bucket.

Another advantage is its being double-acting, with only two valves.

The disadvantages are:—The shock produced by the piston meeting and reversing the current of water.

The great speed of the water in the suction pipe and the consequently increased friction.

Double-acting Piston Pumps.

Advantages:—They take up small space.

Being double-acting, they give a more uniform delivery than the single-acting pumps.

Disadvantages:—When the piston packing is worn, leakage may go on without being detected.

The flat piston meeting the flow of the water.

Usually a great distance or clearance between the suction and delivery valves and the piston.

Continuous Flow Pumps.

The advantages consist in the continuous flow of the liquid into the delivery-pipe, thereby preventing shocks in the same.

Some designs have also the advantage that the water in the pump is always flowing in the same direction, thereby preventing the shocks in the pump itself.

In other designs there is the disadvantage of using cup-leathers when the liquid is mixed with grit, sand, or other impurities.

Centrifugal Pumps.

The advantages are:—The large body of water which they are capable of delivering, as compared with their size and prime cost.

They can deliver sandy, gritty, and muddy water, without any injury to the machine.

They are easily fixed, and require very small and inexpensive foundations.

The disadvantage is that they cannot raise water to any great height.

In comparing centrifugal pumps with ordinary reciprocating pumps, we find that for lifts above 20 feet the results are in favour of reciprocating pumps; under 20 feet, the two classes of pumps are equal; but for lifts of 4 feet to 5 feet, centrifugal pumps have a most decided advantage.

Submerged centrifugal pumps require no foot-valve; where impure water is pumped this is a great consideration.

They do not require charging with water before starting.

They are, however, difficult to clean and repair, having to be lifted out of the pump-well if the water is not let away from it.

Centrifugal pumps with horizontal spindles above the level of the water require little foundation work.

They are easily moved.

They can be fitted on a trolly, and the suction pipe furnished with an universal joint, that it can be raised and lowered at will.

All parts are easy of access for cleaning and repairs.

They must always be charged with water before they will commence sucking, however, and require a foot-valve on the suction pipe, to retain the water when the pump is standing, which valve is detrimental when gritty, dirty, or sandy water is raised.

This latter objection can, however, be obviated in permanent pumping stations, by fixing the pump in a chamber so much below the level of the suction water that the water runs into the casing; by that means there is no necessity for a foot-valve, and the casing, being always full of water, requires no priming; it is advisable in such cases to have a sluice-valve or stop-cock on both the

delivery and suction pipes, which can be closed when repairs or cleaning are required.

The most advantageous application of centrifugal pumps being where the lift required is both moderate in its maximum amount and variable, as when pumping against tidal water or discharging graving docks. In both cases the lift is very small, and varies irregularly to its maximum. Under such circumstances a centrifugal pump possesses peculiar advantages, for it keeps working at its ordinary speed; and with the employment of a nearly constant amount of motive power, it has a faculty of adapting itself to the varying lift.

GENERAL REMARKS ON PUMPS.

Change of direction in the flow of the water should be avoided as much as possible. After a current of water has received an impulse, it is necessary that the motion imparted should be continued with an uniform velocity throughout its whole course; any change in that velocity will cause considerable loss in power, by overcoming the inertia. The motion of a crank moving in a circle with uniform speed is therefore an imperfect machine for moving a pump piston, because the motion which it imparts changes at every point of its course. The pump piston stroke should change suddenly, and its velocity remain uniform. If any irregularity in the motion of a pump piston is advantageous, it is the reverse with the motion of a crank.

Where long suction pipes are necessary, the direct-acting pump motion is by far the best, because the speed of the water is constant through the entire length of the stroke, being proportionate to the movement of the motive power, which is not the case with crank-motion, where the speed of water in the pipe continually changes. In the middle of the stroke, when it should be least, it is above three times as great as the average speed. The best motion for a pump piston being thus: it should commence suddenly, which causes all the delivery valves to close instantly, the piston then should move at a uniform steady speed and finish gradually with a slight pause at the end of the stroke; this latter retardation allowing the pump valves to fall gradually, and when the sudden

commencement of the stroke occurs, the valves are nearly down on their seats.

In calculating the size of pipes for a pump worked by a crank, the quantity must not be taken from the mean quantity discharged, but from the maximum quantity. If an efficient air-vessel is put on the delivery pipe, and a vacuum vessel near the pump on the suction pipe, the variation is not so great; but still it is best to be on the safe side and calculate from the maximum speed. The greatest speed during a stroke occurs when the piston is in the middle of its stroke—that is, when the crank is at the top or bottom, in horizontal pumps; at these points the speed of the piston is equal to the speed of the crank pin, which is found by multiplying the length of the stroke in inches by 3·14. This gives the distance the crank pin travels in one revolution; multiplying this by the number of revolutions per minute and divide the product by 12, the result being the speed in feet of the piston in the middle of the stroke.

The late Mr. Thomas Box gives, in his valuable book on 'Hydraulics,' published by Messrs. E. and F. N. Spon, the following interesting table, showing the variation in the velocity in different kinds of pumps without air-vessels:—

	Maximum.	Mean.	Minimum.	Variation per cent.
One single-acting pump, worked by a crank	314·16	100	000	314·16
Two ditto	222·00	100	000	222·00
One double-acting pump ..	157·08	100	000	157·08
Three-throw single-acting ..	104·76	100	90·69	14·07
Four single-acting, or two double-acting	111·00	100	78·79	32·21

This table clearly proves that the ordinary treble barrel pumps have the most uniform delivery, the maximum velocity being under 5 per cent. in excess of the mean; an air-vessel is hardly necessary for these pumps.

Pump Valves.

The most important parts of a pump are its valves; let the design be good in all other respects, the performance of the pump will be seriously affected if the valves are of an unsuitable type, or bad in workmanship and design. A large portion of the power lost in a pump is greatly due to these defects; it is therefore very important that great care should be taken in designing to obviate them, and a careful choice made of the class of valves that are most suitable for the work to be done.

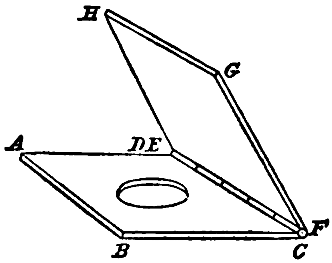
The duty of a valve is twofold:—*Firstly*, it should afford an unobstructed passage for the water in one direction; *Secondly*, it should close the passage entirely, and prevent the return in the contrary direction. For a valve to fulfil the first condition, it must not contract the area of its waterway, or in any way obstruct the flow of the water; it must move with the same velocity as the water, and it must be of the same weight as the water it displaces, so as not to cause any resistance to the ascending water. To fulfil the second condition it must be heavy enough to close by its own weight before the pump commences the return stroke, so as to prevent the valve from banging; and it must have very little lift, in order to produce the least amount of "slip."

It would be useless to advocate the universal adoption of one particular class, as the conditions under which they are employed are so numerous that a single type would fail to fulfil all the requirements.

The number of different valves are legion, the writer will give only a few samples of the best and most commonly used.

The oldest valve is probably the metal clack valve, as it is mentioned and illustrated in Hero's work on

FIG. 143.



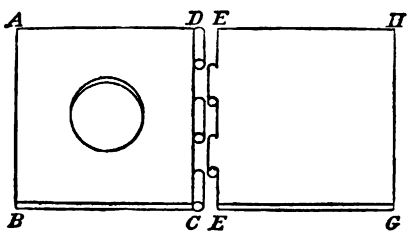


FIG. 144.

"Pneumatics." The illustrations Figs. 143 and 144, and the description are taken from that book :—

"A valve for a pump. The following is the construction of the valve referred to. Take two rectangular plates of bronze of the thickness of a carpenter's rule, and measuring about one finger's breadth ($\frac{7}{10}$ of an inch) on each side. When these have been accurately fitted to

each other, polish their surfaces so that neither air nor liquid may pass between them. Let A B C D, E F G H (Figs. 143 and 144) be the plates, and in the centre of one of them A B C D, bore a circular hole about $\frac{1}{3}$ of a finger's breadth ($\frac{1}{4}$ of an inch) in diameter. Then applying the sides C D to E F, let the plates be attached by means of hinges, so that the polished surfaces may come together. When the valve is to be used, fasten the plate A B C D over the aperture, and any air or liquid forced through will be effectually confined. For by the pressure exerted the hinges move, and the plate E F G H opens readily to admit the air or liquid; which when inclosed in the air-tight vessel, presses on the plate E F G H, and closes the aperture through which the air was forced in."

From the same book it appears that the spindle valve was also known to Hero, for he says:—"In the cylinder bases pierce circular apertures, covered with polished hemispherical cups, through which insert spindles soldered to, or in some way connected with, the bases of the cylinders, and provided with shoulders at the extremities that the cups may not be forced off the spindles."

The most common is the clack valve, which consists of a piece of leather or canvas, covering an orifice and held down at one edge, which forms a hinge; the leather is at the centre covered top and bottom by metal plates, to make it rigid, and to add weight, so as to enable the valve to close.

There are two classes of pump valves: one consists of mechanically-moved valves, the other of automatically-moved valves.

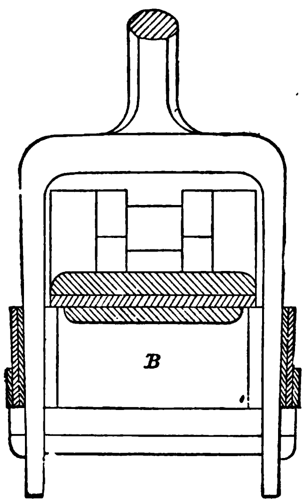
The first class consists of either ordinary slide valves, as illustrated in Fig. 28, or piston valves, as illustrated in Fig. 98; they are seldom used except for semi-fluids, such as tar, treacle, &c.

The other class is so numerous that it would take a whole volume to give anything like a complete description of them. The author must therefore confine himself to a few of the most common types.

Clack Valves.

The ordinary clack valve is shown in Figs. 145 and 146, and consists of a cast-iron, wrought-iron, or gun-metal

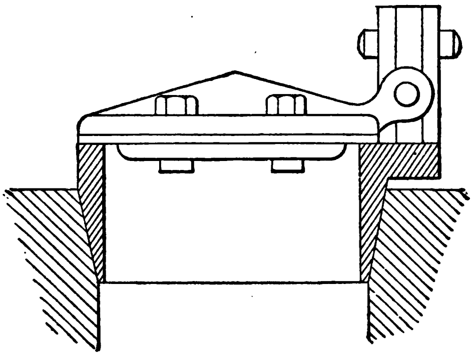
Fig. 145.



plate, provided with a hinge pin, working in two forks provided on the seat; the valve is faced with leather, canvas, indiarubber, gutta-percha, or vulcanised fibre; the facing material being secured by means of a plate and screws or rivets, the former being preferable, as when the

leather is worn out the nut can be unscrewed in a few minutes and a new facing put on.

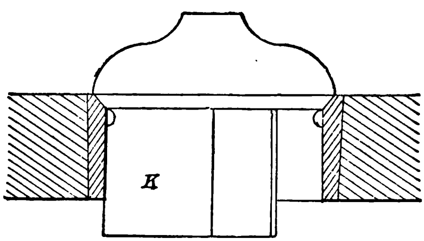
FIG. 146.



MITRE VALVES.

There are numerous designs of this type; one is illustrated in Fig. 147. It consists of a gun-metal plate

FIG. 147.

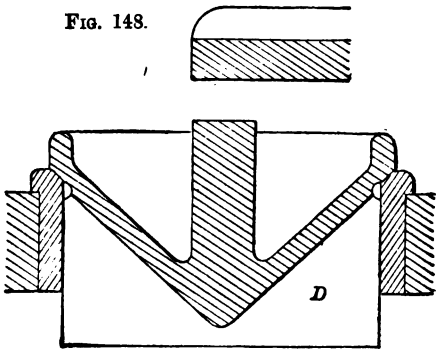


furnished on its underside with three or more wings or guides (according to the size of the valve), turned to fit the gun-metal seat.

Fig. 148 illustrates, in the Author's opinion, the best

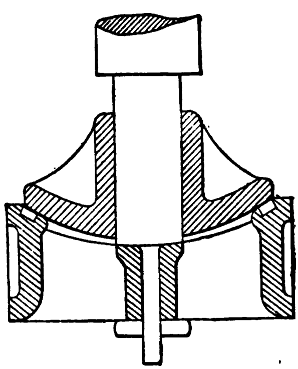
valves of this type, because the conical shape of the valve guides the water into the proper direction, and causes the least contraction of the fluid vein.

FIG. 148.



ANNULAR RING VALVES.

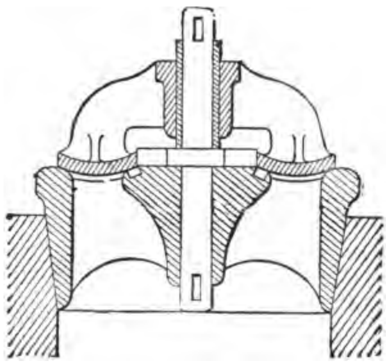
FIG. 149.



The valve illustrated in Figs. 149 and 150 is called annular ring valve, because it consists of a ring having

beats both at the centre and round the periphery, and delivers the water both through the centre and round the periphery; it is guided on the centre spindle.

FIG. 150.



REMARKS ON DESIGNING PUMP VALVES.

The lift of the valves should be of such height as to give a full and clear passage for the water to flow through. The area of the valve opening in inches, divided by its circumference in inches, equals the height of the lift required for the valve, which equals one-fourth the diameter of the valve. This is for valves that lift perpendicularly, as in Figs. 147 and 148. But in clack or flap valves, as in Figs. 145 and 146, which are hinged, the lift should be taken at the centre, to give the opening required; in no case should the angle be greater than 60 degrees, because the distance to travel is so great that a quantity of water will have time to "slip" back into the suction-pipe before the valve closes the passage. As a rule, the valves ought to be made larger in diameter and given low lift, by that means diminishing the quantity of "slip," as this loss of water is technically named. Most horizontal pump makers have the suction-pipe one-third the area of the pump barrel or ram, and the delivery one-fourth. Others make the suction one-half and the delivery one-third of the area.

Whenever large metal valves are employed they should be made to beat or fall—not upon seats of iron, brass, or hard metal, but upon faced rings of hard wood, let into the part which would otherwise form the seat for the valve. By this means the blow is rendered softer, and less likely to fracture or otherwise injure the valve and

seat. Sometimes a soft metallic alloy of lead and tin is used for the facing instead of wood. But wood has the additional advantage of preventing any galvanic action between the faces of the valve and valve seat, which, with saline water, has been found to do mischief. Metal valves, however, succeed better in waterworks than in collieries and mines, where the bad quality of the water is generally an obstacle to their use. Leather valves, or valves faced with leather, are generally preferred by pitmen, because they are less liable to slip or to stick open. The valve shown in Fig. 150 shows a valve at the Wolverhampton waterworks. It is of the annular ring type, rising on a centre spindle; made of cast-iron, galvanised, beating on wooden faces. Originally they beat upon a mixture of lead and tin, but they soon became loose in their seatings and leaked; oak was then tried, but the acid corroded the cast-iron; these beats were taken out; lancewood, boxwood, and beech were also tried, but nothing answered as well as holly, which was put in in the year 1856. Since then it has been found that lignum vitæ is the best kind of wood for the beats. Mr. Henry Davey, of Leeds, made the bottom beats of gun-metal, and the top ones of hippopotamus hide. The leather beat is secured against damage by grit by being placed on the top instead of the bottom. At present he uses the best quality of specially prepared cow hide.

When leather or indiarubber is used for valves, all corners of contact should be carefully rounded off, or else the material will be soon cut.

At Clay Cross Colliery, near Chesterfield, clacks faced with leather were used and only lasted forty days. Their late engineer, Mr. William Howe, the original inventor of the so-called Stevenson's link motion, tried gutta-percha, this lasted 150 days; at last he tried vulcanised fibre,

which lasted 171 days. This proves conclusively the superiority of the fibre for that purpose and quality of water.

All ribs and wings should be placed at such an angle that when the valves lift it will partially rotate, and by so doing the same part of the valve and seat will not come together at two consecutive beats. The valve faces will, therefore, last much longer.

Arrangements of buffers and closing springs of indiarubber, are illustrated in Figs. 151, 152, 153, and 154. Fig. 151 consists of indiarubber washers, but they were not elastic enough, so round iron rings were put between

FIG. 151.

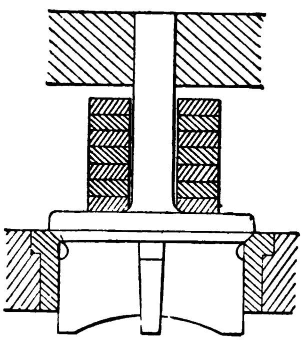
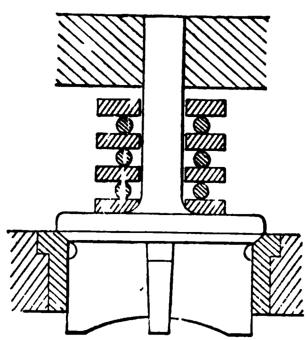


FIG. 152.



the washers, as shown in Fig. 152, but the rings cut the rubber. The arrangement illustrated in Fig. 153 was tried, it consisted of round indiarubber rings and flat plates. In this case the plates were too small in diameter; the rings worked over the plates. Now the plates are made of cast-iron or gun-metal with a bead round the edge, as shown in Fig. 154; these work admirably.

In 1873 Mr. S. Holman patented the application of

indiarubber tubular buffers to suspended valves for rapidly closing the valves. These arrangements of springs prevent the valves from knocking the top when lifting,

Fig. 153.

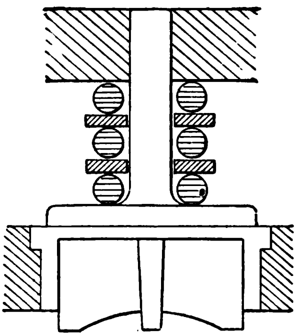
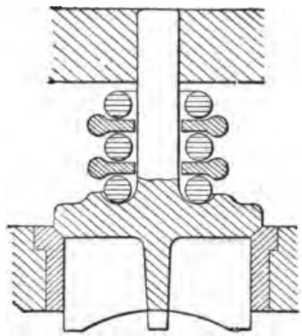


Fig. 154.



and the seats when closing, or reduce it to a minimum. Steel and brass springs are also used for different kinds of liquids.

Fig. 155.

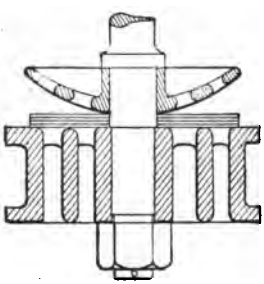
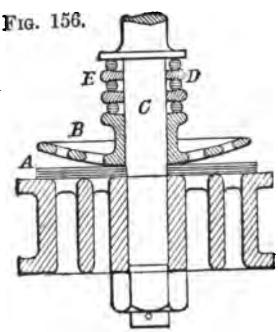


Fig. 156.



The usual way in which buckets are made for horizontal bucket pumps is illustrated in Fig. 155, but a better plan is illustrated in Fig. 156, in which the guard B is made

to slide on the rod C, making the guard very flat, so that the indiarubber is prevented from bending too far; but to compensate for that, and to allow the rubber to part from its seat a distance great enough to give free passage for the water, the guard slides, and is kept to its work by means of the three indiarubber rings D, and the two plates E. A is the indiarubber disc.

Pump valves should be made of cast-iron, leather, and gun-metal for water; cast-iron, cast malleable iron or wrought iron for ammoniacal liquor and tar; gun-metal for weak acids, malt liquor and treacle; for hot water gun metal, or specially prepared indiarubber; for strong acids, antimony.

Spears and Well-rods.

The spears and well-rods are made of wood, solid wrought-iron, and wrought-iron or steel tubes.

The wood spears should be made of perfectly sound Memel timber, free from defects or knots, and of the greatest length possible, the lengths varying from 10 to 15 yards; but, whatever the length may be, all the rods should be exactly of the same length, so that a spare rod will fit any place. The safe load for the rods is 5 cwts. per square inch, but as the weight required on the spear usually is very great, a much larger margin is consequently given.

The length of the spears should be carefully half-lapped and held firmly together at the joints by strong wrought-iron plates, technically called "strapping-plates," bolted through the timbers by strong bolts.

The bolts for small wood spears are usually made cup-headed and have square nuts; for large spears square

heads and nuts. The holes in the strapping-plates should be square, and the bolts square under the heads.

Sometimes cast-iron strapping-plates are used, where weight is required, instead of wrought-iron; for this purpose the plates are arranged so that the bolts pass outside the timber, the rod thus retaining its strength throughout.

Ofttimes in practice two wrought-iron plates are used; this is decidedly bad, for it only ensures rigidity one way. The best method is to have one plate on each side of the rod, although it weakens the rod by the cross-holes for the bolts; but as the rods usually are much larger than is necessary, it need not be taken into consideration.

The spear rods are usually at intervals guided by frames or cross-pieces secured to the sides of the pit shaft; sometimes cast-iron guides are used; in either case the spears, where they pass through the guides, should be cased by hard wood, well greased, to prevent the wear caused by friction.

In mines and coal-pits the water is usually raised in stages—that is, a pump, generally of the bucket-type, is fixed at the bottom, thus delivering the water to a tank or cistern, made of wood or iron, in which a plunger pump is fixed, drawing or sucking the water from the tank; this forces the water between 40 to 50 yards into another tank, and so on to the top of the pit or shaft.

Originally there was a long spear of wood from each pump, reaching to the top, where they were joined into one main rod; but now there is only one main rod used, to which all the plunger poles and the bucket rod are secured by "set-offs."

The deep well pump rods are made of solid wrought-iron, as a rule, and the part which is in contact with the water is made of gun-metal. Müntz metal, or copper.

Hollow tubes of wrought-iron have been introduced during the last few years, the author believes that they were originally used in America. They are frequently used in the colonies on account of their lightness.

In some cases the hollow tube is used as the rising main, in which case it is made of cast-iron or wrought-iron, according to the size of the pump; the latter is preferable. This arrangement is illustrated in Fig. 133, and fully described on page 166.

The different arrangements of wooden spears are obviously very expensive and cumbersome, taking up a very large space in the pit shaft. Many plans have been devised and tried to do away with them, having more or less merit, and all of them open to objections.

One plan is to have the engine and boiler underground, simply having the delivery pipe from the pump carried up the shaft. The objections to this system are: that, in the case of metalliferous mines the coal has to be taken down the shaft into the workings, and utter failure may result at a most critical time, as for instance, when a great and sudden influx of water or an outburst of gas occurs and the men are driven out of the mine or pit.

Another plan, which is now very frequently adopted, is to place the boiler at the top of the shaft and the pumping engine underground. This system is not without its faults. There being, of course, only two pipes in the shaft, the size of the shaft can, when new shafts are sunk, be made of a less size, consequently reducing the first cost materially; these pipes being one for steam and one the rising main from the pump to the surface of the pit top or an adit. The objections are the reduction of the steam pressure through condensation of the steam in the pipes going down the shaft; also the heat from the steam pipes, which in small workings becomes very great. This

system is of course also open to the objection that the steam engine cannot work very economically under water in case of a sudden inburst of water.

To prevent this latter objection, hydraulic engines have been fixed at the bottom of the working, and a steam engine placed a distance, say 50 to 100 feet, from the bottom of the shaft.

Another system, invented and patented in the year 1872 by Mr. G. G. Andrée, was introduced as a substitute for the rods, and from experiments have proved successful. It consists in transmitting the force developed by the water at surface to the pumps at the bottom of the mine through columns of water. There is, of course, nothing new in the principle of this system. The perfect manner in which force may be transmitted through pipes filled with water has been demonstrated by the well-known hydraulic machinery, which owes its origin to the inventive genius of Mr. Joseph Bramah and Sir William Armstrong, in which the employment of a column of water constitutes an essential feature.

Mr. Andrée's system consists of two pipes filled with water going side by side down the shaft or well, connected at the top by a motor-cylinder. When the piston in the latter is moved one way water-pressure is conveyed down one pipe, in the opposite direction down the other pipe. Or one pipe may be connected to its motor cylinder, the pistons on the latter being worked in opposite directions. Underground the two pipes are connected to a pump having two pistons.

A great difficulty was at first found to exist in this system, namely, to keep the pressure pipes quite full of water, and also to preserve an equality in each of the pressure cylinders; this difficulty has been overcome by having the motor cylinder in constant communication

with a reservoir cylinder through a pipe. The pipes are provided with valves or cocks, worked by hand, for the purpose of cutting off the communication when necessary. A ram or piston works in the reservoir-cylinder through a stuffing-box, and is loaded to the proper pressure per square inch which has been found requisite to work the pump, the weight being suspended from a cross-head by rods. As the water in the motor-cylinder is in constant communication with that in the reservoir, any leakage that may occur in the pressure-pipe or the pumps is instantly replaced. Consequently the pipes must be always full; and as no inequalities can possibly occur, the rams in the cylinders cannot be displaced.

Several improvements on this system have been introduced into this country within the last few years, by Mr. Ralf Moore, of Glasgow, being the inventions of Mr. Joseph Moore, of San Francisco.

The pump rods for direct-acting steam pumps are usually made of mild piston-rod steel, but when the pump is used for raising salt water, treacle, and malt liquor, they are made of Müntz metal, gun-metal, or phosphor bronze; the latter is also frequently used for direct-acting mine pumps, and in many cases, as at Wharncliffe Colliery, near Sheffield, the water is so bad that even the phosphor bronze is corroded away in a very short time.

For direct-acting steam pumps used for pumping treacle or other thick fluids, the distance between the steam and pump cylinders should be such that the part of the rod that enters the pump cylinder shall never enter the steam cylinder.

AIR-VESSELS.

The air-vessel is a chamber of cast-iron, wrought-iron, steel, or copper, provided to maintain a constant flow, to increase the efficiency of a pump. A single-acting pump, for instance, loses power in consequence of the piston having to set the superincumbent column of water in motion at each stroke. A double-acting pump is in this respect similar to a single-acting pump, but in a three-throw pump the flow is continuous; so also are the continuous flow and properly constructed duplex pumps, where, for this purpose at least, an air-vessel is superfluous.

A more important use of a reservoir of air is to relieve the pressure, and so prevent shocks. The air-vessel possesses the serious defect of requiring, in some cases constant, in others frequent replenishing, in consequence of absorption of the air by the water. The rapidity with which the air is exhausted in the vessel depends on the pressure to which it is subjected; the greater the pressure the sooner the air is absorbed. In consequence, an air-vessel cannot be applied at all when the pressure is very great, as in the case of high lifts in collieries and mines, or for working hydraulic machinery; in the latter case the accumulator and treble-barrel or duplex pumps are the remedies.

In America the absorption of air is prevented by having a closed rubber bag filled with air, which will have all the elasticity of the air space, without being liable to lose its cushion power. This arrangement was patented in England, in the year 1861, by Messrs. M. and R. M. Merryweather.

A good apparatus for supplying air to the vessel was patented by Messrs. Wipperman and Lewis; it consists of a cylindrical vessel, which has no working parts, the water

itself forming the piston; at the bottom of the chamber is a small pipe, fitted with a regulating cock, which is attached to the pump valve-box, immediately below the delivery valve; at the top of the vessel is fitted a small gun-metal valve-box, fitted with inlet and outlet air valves, and from this a delivery pipe communicates directly to the air-vessel. The action of the apparatus is as follows, viz.:—when the main pump draws its water it will partly empty the vessel, the amount being indicated by a gauge and regulated to a nicety by the cock; on the return stroke of the plunger pump, the whole of the air drawn into the vessel is sure to be delivered into the air-vessel, because the pressure in the main pump when delivering is in all cases greater than on the suction side.

Another apparatus for charging large air-vessels with air is used at Exeter waterworks. In this case the air-vessel is divided into two parts horizontally by a diaphragm. The bottom part is furnished with a blow-off cock. A pipe fitted with a wheel-valve is furnished, putting the bottom part of the top chamber in communication with the bottom part of the bottom chamber. Another pipe forms a connection between the top part of the upper chamber and the top part of the lower chamber. This latter pipe is furnished with a wheel-valve for closing the communication between the two chambers, and below the valve is fixed, in the same pipe, a small valve communicating with the open air.

To charge the vessel with air, proceed in the following manner:—

Open the small valve communicating with the open air and the blow-off cock at the bottom chamber, to empty it of water and fill it with air.

Close the air cock and the blow-off cock.

Open the valve which is fitted in the pipe communi-

cation between the bottom of the top chamber and the bottom of the lower chamber, which causes the water to enter the bottom chamber from the top chamber.

Then open the valve on the pipe communicating between the top of the top chamber and the top of the lower chamber, which allow the air in the lower chamber to rise into the top of the upper chamber. This being effected, close all the cocks.

There are several distinct types of air-vessels.

One consists of a large cylinder contracted at each end to the diameter of the rising main or delivery pipe, and having a pipe inserted for the delivery of the water. This pipe is brought nearly to the bottom of the chamber, leaving an annular space in which the air is compressed; this pipe is named the "dip" pipe. This plan is not to be advocated, because the air, rising in the most direct way, allows very little of it to rise into the annular space. When the dip-pipe arrangement is used, the delivery from the pump ought to be admitted about half-way up the vessel—not at the bottom, which is the usual practice.

Another type of air-vessel usually fitted to direct-acting steam pumps and pumping engines, consists of a large pipe with a semi-circular top; the bottom is contracted, and provided with the inlet and outlet branches.

A third type consists of a large dished or hemispherical topped vessel, provided with a branch at the bottom and another on the side, or one on each side near the bottom. These air-vessels are generally made completely of cast-iron. Sometimes the base or bottom part is of cast-iron and the vessel proper of wrought iron or steel plates, riveted or welded together in the seams.

In some instances the air-vessel is made double—the lower part serving as a suction or vacuum vessel, connected by a branch to the suction-pipe; the upper part

forms the delivery, or air-vessel proper. This is a very convenient arrangement when space is limited.

Elastic air-vessels are frequently used in Germany and France: of these there are three types, one consisting simply of an indiarubber tube, secured to the delivery branch on the pump and the delivery pipe or rising main by brass couplings.

Another consists of two pipes, one having one end blocked up and sliding inside the other. Both cylinders are provided with strong rugs, over which are stretched indiarubber rings or bands strong enough to resist the greatest water pressure against which the pump has to work.

The last of this class of air-vessels consists of an indiarubber balloon, working against a shield, which latter determines the expansion of the air vessel.

Pipes.

Pipes are a very important item in a pumping plant and very frequently a very serious outlay, and ought, therefore, to receive a great share of attention.

The ancients, as far as we know, used very few pipes, they generally made culverts of brick or cement. They sometimes used lead pipes, but of a very small diameter only, because on account of the imperfect manner in which they were made, they could not resist any great strain. These pipes were made of long strips bent cylindrical and joined at the edges.

As we have previously seen, on page 7, the pipes for the first London waterworks were made of lead.

At Bethlehem Waterworks, in America, they were made of hemlock logs bored out. In 1762 the force mains were of gum wood, and the distributing pipes of pitch-pine—the

latter had to be renewed in 1769. In 1786 lead pipes were substituted for the gum-wood force mains and most distributing pipes. The last pitch-pine pipes were abandoned in 1791. In 1874 the wooden conduit from the spring to the pump house was replaced by an 18-inch iron pipe. It was not until about 1810 cast-iron pipes were introduced in America.

In Cornwall we find them busy making wood wind-bores for their pumps in 1798.

Now of course cast-iron is mostly used for large pipes, and wrought-iron and lead for smaller pipes, although a short time ago, an American firm obtained a large order for large pipes made of strips of wood, on account of the lightness, they being required for transportation.

The usual manner in which the large wrought-iron pipes are made is to have a straight longitudinal riveted joint or seam, but an American firm (the "Abendroth and Root Manufacturing Company," New York) make wrought-iron pipes with the seam spiral, by that means strengthening the pipe.

To prevent corrosion in the pump "trees" and rising main in Cornwall, they are made larger in diameter and lined with staves of wood fitted with great care, otherwise the cast-iron pipes will soon be eaten away by the corrosive action of the acid contained in the water. The staves are put round the interior of the pipe, a narrow space being left between the first and the last stave; into this space are driven two wedge-shaped pieces, one driven in from each end of the pipe.

A good plan to prevent corrosion is to heat the pipe by steam, then coating it with melted pitch, both inside and outside.

Another method is to use Dr. Angus Smith's process, which is as follows:—The pipe must be thoroughly

cleaned from mould, sand, and rust, heated to about 700 degrees Fahr., then dipped vertically into a mixture of coal tar, pitch, linseed oil (5 to 6 per cent.), and rosin, heated to about 300 degrees Fahr., and allowed to remain until the iron acquires the temperature of 300 degrees Fahr., when they are gradually withdrawn and allowed to cool in a vertical position.

To prove what effect corrosion in pipes has upon the friction of the water, it is stated, in "Spon's Dictionary of Engineering," that Darcy's experiments showed that the effect of corrosion was to double the friction, consequently it will be necessary in the case of corroded pipes to double the head due to friction found by formulas. A case is recorded as having occurred at Torquay, where a main about 14 miles long, composed of 14267 yards of 10-inch, 10085 yards of 9-inch, and 172 yards of 8-inch pipe, delivered only 317 gallons a minute with 465 feet head. An ingenious scraper, worked by the pressure of the water, was passed several times through the pipes, the result being a discharge of 634 gallons.

Besides the loss of power by friction, there is the loss by change of direction, through elbows and bends. The less the angle and the larger the radius, the less loss of power.

To the head due to friction and to the resistance offered by bends must be added the head due to the velocity of entry. In long mains this quantity is so small a proportion of that due to friction that it may be neglected without sensible error; but in short pipes it may be much greater than the head due to friction, and, therefore, in such cases it cannot, of course, be neglected.

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